For Editorial Contents see page 565

ENGINEERING LIBRARY JAN 2 1948

ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY CHAS. COOPER AND J. FOSTER PETREE.

OFFICES FOR ADVERTISEMENTS AND PUBLICATION, 35 & 36, BEDFORD ST., STRAND, LONDON, W.C.2

VOL. 164—No. 4272 *Registered at the General Post Office as a Newspaper* *LONDON: FRIDAY, DECEMBER 12, 1947.* PRICE 1s. 6d. POSTAGE {INLAND 2½d. FOREIGN 3d.

LOCOMOTIVES
STEAM OR DIESEL
HUDSWELLCLARKE&Co. Ltd.
RAILWAY FOUNDRY, LEEDS.
London Office: 46, Victoria St., S.W.1.
Telephone: Victoria 1133 8559

DOUBLE YOUR LOADS
WITH 5552
DYSONTRAILERS

INJECTORS
FOR ALL PURPOSES
GRESHAM & CRAVEN, LTD. Manufacturers.
ORDSALL LANE, SALFORD, MANCHESTER, 5.
Phone No.: Telegrams:
BLAckfria.s 6316. Brake Phone, Manchester.
London Office: 5476
14 Great Peter Street, Westminster, London, S.W.1.

WISEMAN
REDUCTION GEARS
ALFRED WISEMAN & CO. Ltd.
GLOVER STREET, BIRMINGHAM, 9.

DREDGERS
OF ALL TYPES
FERGUSON BROS. (Port-Glasgow), LTD.
PORT-GLASGOW 5290

J. & E. HALL
REFRIGERATION
FOR LAND & MARINE PURPOSES
LIFTS AND ESCALATORS
J. & E. HALL, LTD., ENGINEERS, DARTFORD KENT.
Telephone: Dartford 3456.
London Office: 10, ST. SWITHIN'S LANE, E.C.4.
Telephone: MANSION HOUSE 9811. 5492

LIGHTALLOYS LTD
FIRST QUALITY 4189
ALUMINIUM CASTINGS
ALPAX WORKS, St. Leonard's Road, Willesden Junction, London, N.W.10. Telephone: Elgar 7191-2-3-4. Telegrams: "Lightalloys-Phone-London"

DANIELS
FOR
PLASTICS MOULDING PLANT
T. H. & J. DANIELS LTD.
STROUD, GLOS. Tel. 661/2/3. 5000

YARROW
& CO., LTD.
GLASGOW
SHIPBUILDERS
MARINE ENGINEERS 4893
LAND AND MARINE BOILER MAKERS

CRADLEY BOILERS
CRADLEY BOILERS CO. LTD.,
CRADLEY HEATH, STAFFS. 5585

BROTHERHOOD
AIR AND GAS
COMPRESSORS
PETER BROTHERHOOD LTD.
PETERBOROUGH. 6938

BIBBY COUPLINGS 5200

CRANES
GEORGE RUSSELL & CO., LTD.
Motherwell. 4876

TWIN DISC CLUTCHES
AND HYDRAULIC COUPLINGS
BRITISH TWIN DISC & CLARIFIERS LTD.,
ALDWYCH HOUSE, LONDON, W.C.2. 5165

WATER TREATMENT
UNITED FILTERS
& ENGINEERING LTD.
BURSTON ROAD, PUTNEY,
LONDON, S.W.15. 5319

SPRINGS BY RILEY
TECHNICAL LEADERS SINCE 1821
High-grade springs for every conceivable purpose. On Admiralty, War Office and Air Ministry Lists.
ROBERT RILEY LTD
MILKSTONE SPRING WORKS,
ROCHDALE Telephone 2237/8 (2 lines)

RAPIER
EXCAVATORS
and
WALKING DRAGLINES
RANSOMES & RAPIER LTD. Ipswich - England 5199

STEPHENS V-BELT DRIVES
Send for copy of V-Belt Drive Data Chart
STEPHENS BELTING CO. LTD
V-DRIVE WORKS,
SNOW HILL, BIRMINGHAM, 4

MUREX
Electrodes
MUREX WELDING PROCESSES LTD.
WALTHAM CROSS, HERTS. 5214
Telephone: Waltham Cross 2636

PUMPS.. Tel.
London Holborn 4271 (5 lines) Newark 601-2-3-4
Manchester Blackfriars 3810 Newcastle 22333
Birmingham Midland 5310 Glasgow Douglas 1974
Liverpool Central 1877
WORTHINGTON - SIMPSON

BARRY SCREENS
BARRY, HENRY & COOK, LTD.
ABERDEEN. 5586

BYFORDS
CAN REBUILD THAT MACHINE TOOL
EFFICIENTLY ACCURATELY
ECONOMICALLY
AT
GRICE ST. WORKS, WEST BROMWICH, STAFFS.

HEATING AND VENTILATING
SCIENTIFICALLY PLANNED.
Complete systems installed embodying the latest principles of space heating, ventilating, dust and fume removal, high pressure hot water and steam systems for heating and process work. Also pipe systems for compressed air, gas and oil.
Consult Us About Your Particular Requirements
SAUNDERS & TAYLOR LTD.
IMPERIAL BUILDINGS,
13, OXFORD ROAD, MANCHESTER 1
51, BOROUGH HIGH ST., S.E.1

FRICTION CLUTCHES
PATENT DISC AND CENTRIFUGAL TYPES
Satisfaction Guaranteed
W. R. ANDERTON & CO.
Clutch Specialists
CASTLETON, ROCHDALE
Tel.5854 Castleton ROCHDALE

COOPER SPLIT ROLLER BEARINGS
KING'S LYNN 5381 NORFOLK

FLEXIBLE TUBING
NON-METALLIC
Internal diameter from ¼ in. to 10 in.
for
PETROL - OIL - WATER - DUST EXTRACTION
HIGH OR LOW PRESSURE & TEMPERATURE
COMPOFLEX CO. LTD. 14, Dartmouth St. LONDON, S.W.1.
Tel.: Whitehall 6411/2. 5522

"RAPIDOR"
Registered Trade Mark
MACHINE TOOLS 4688
EDWARD G. HERBERT Ltd.,
LEVENSHULME——MANCHESTER, 19

ALLDAYS & ONIONS
5353 BIRMINGHAM LTD.
BLOWERS ROOTS AND ROTARY

SPENCER-BONECOURT
Patent Waste Heat Boilers
34/36, Farringdon Street, E.C.4. 4971

WELDED PLANT
FABRICATION IN MILD & STAINLESS STEEL
HOMOGENEOUS LEAD LININGS.
GREY IRON CASTINGS (12 TONS).
MACHINING FACILITIES—20 FT. DIA. MAX.
M. & W. GRAZEBROOK
(EST. 1750) LTD.
DUDLEY, Worcs. 5491

RESEARCH
ENGINEERS LTD
FOR
PROTOTYPES
FOR DETAILS
SEE FIRST CLASSIFIED PAGE

PULSOMETER PUMPS
REFRIGERATION
WATER PURIFICATION
PULSOMETER ENGINEERING CO. LTD., READING.
Telephone: READING. 67182 TILEHURST
LONDON. 4565 ABBEY.

HIGGS MOTORS
TRADE MARK
CHAIRMAN WALTER F. HIGGS, M.I.E.E. LTD.
BIRMINGHAM 6 ENGLAND

All windings fully enclosed. External cooling system. Ample inspection points. Maximum reliability.

AND

GUARANTEED FOR EVER!

HEAD OFFICE & WORKS
WITTON, BIRMINGHAM, 6, ENG.
TELEPHONE BIRCHFIELDS 4545 BR. EXCH.
TELEGRAMS "HIGSWITON"

BRISTOL DUNDEE
GLASGOW NOTTINGHAM
LONDON PETERBOROUGH
MANCHESTER SHEFFIELD
BELFAST

5215

THE STORY OF ATOMIC ENERGY.

V.—THE DISCOVERY OF ATOMIC ENERGY.

By DR. FREDERICK SODDY, F.R.S.*

IN the spring of 1900, the writer, who had graduated in chemistry at Oxford in 1898, was in Canada applying for an academic post he did not get. Attracted by the magnificent Macdonald Laboratories of McGill University, he remained there and obtained a demonstratorship in the Chemistry Department. Rutherford at the time was in New Zealand, getting married; but when he returned to Montreal, and the writer had learned from him first-hand about his discovery of the emanation of thorium, he abandoned the chemical research on which he had started, and, at Rutherford's invitation, joined him in a joint physical and chemical investigation of the radioactivity of the compounds of thorium, which lasted over two years and at the end had been extended to include all the radio-elements.

What was the chemical character of these gas-like emanations, requiring no more than a puff of air to separate and study by themselves by means of the rays which give their presence away, though in quantity inconceivably small? To a chemist, it was natural to inquire and it was one of the first questions investigated, when, in the winter term of 1900, the writer joined Rutherford in this work. By a most fortunate circumstance, this one investigation practically of itself settled the question, for the answer was in the negative. The radioactive emanations have no chemical properties at all, but can be passed without loss through all the chemical reagents, and subjected to all the chemical methods known to absorb gases, completely unchanged.

THE EMANATION IS AN ARGON GAS.

This story opened with the year 1895. It should have been 1894, for this was the year the late Lord Rayleigh and Sir William Ramsay discovered argon, named from the text "Why stand ye here all the day idle doing no work?" But for that 1894 discovery, the result would have meant nothing. As it was, it meant one thing only: that the emanations are argon gases. This conclusion was reached quite definitely early in 1901. By then the inert constituents of the air were known to form a complete new zero-valency family of gases in the Periodic Table, all of them devoid of chemical combining power, comprising, in order of atomic weight, helium, neon, argon, krypton, xenon, and now including the three isotopic emanations, renamed radon, thoron and actinon. These last are next to xenon in the zero-valency family, just as radium is next to barium in the family of bivalent alkaline-earth elements. A liquid-air plant was specially given to the Macdonald Physics Building by its generous founder for continuing this work, and as soon as it could be installed it was found that the emanations, quite unaffected by the lowest temperatures previously available, —100 deg. C., are completely condensed by liquid air at —150 deg. to —155 deg. C. This property enables radon to be obtained easily in the pure state and was to prove absolutely invaluable, both to theory and practice.

THORIUM X AND URANIUM X.

Long before this could be done, however, something else let the cat out of the bag much more informatively than the negative chemical character of the ephemeral thoron. It was found that the latter was not a direct product of thorium, but of an intermediate substance we named thorium X, which has a half-period of four days, just right, as it happens, for the human experimenter to get quick results without being hurried. Th X, being as now known isotopic with radium, was chemically separated from thorium by a simple precipitation of the solution with ammonia. It was the continuous regeneration by the thorium after removal of this thorium X, and numerous precisely similar cases, that settled decisively the production versus induction issue.

One such example in particular must be mentioned. In 1900, Sir William Crookes had succeeded, by several simple and elegant chemical methods, in removing from uranium the constituent, which he called Uranium X—after which by analogy Thorium X had been named—which was as he thought responsible for the whole radioactivity of uranium, the latter being concentrated in the minute quantity of impurity separated from the uranium. Similarly, Becquerel, by successively precipitating barium as sulphate in uranium solution a large number of times, had much reduced the radioactivity of the uranium, the barium sulphate being made radioactive.

Repeating this work for uranium, the writer, at first using Rutherford's ionisation methods of

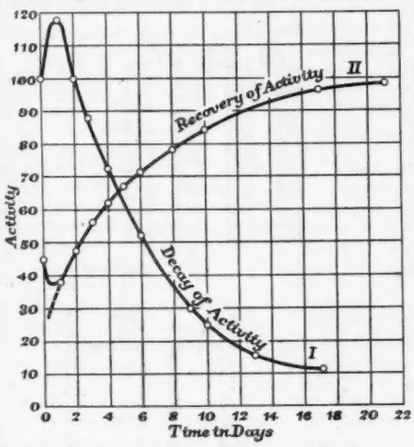


FIG. 26. DECAY AND RECOVERY CURVES OF THORIUM X AND THORIUM (α-RAYS).

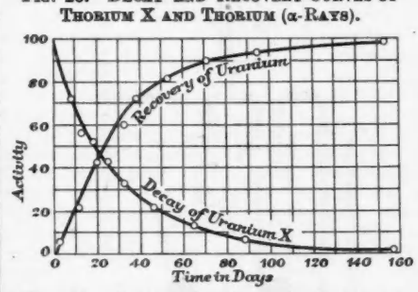


FIG. 27. DECAY AND RECOVERY CURVES OF URANIUM X AND URANIUM (β-RAYS).

measurement, got no separation or reduction of the radioactivity of uranium by any of the chemical processes. Then, repeating the work using photographic methods of detecting the radiation, he obtained the same results as those got by Crookes, who used only this method. From this it transpired that the photographic effect of uranium is entirely due to the β-rays. No chemical process has even yet been found capable of reducing in the slightest degree the α-radiation of uranium.

Both Crookes and Becquerel found that the uranium rendered photographically inactive by chemical treatment recovers in time its activity, and that the uranium X separated becomes completely inactive, just as with thorium, after removal of thorium X. From his experiments Becquerel concluded that the activity of the barium sulphate was an induced, or "false," radioactivity due to its association with the uranium; but the recovery and decay are in this case much slower, some nine months instead of one month being required for completion. This much longer period, no doubt, as well as the now exploded hypothesis of radioactive induction, contributed to the true explanation being first arrived at for the very complex case of thorium, rather than for the simple straightforward case of uranium. On the other hand, the very complexities of the thorium disintegration, once the correct interpretation was glimpsed, provided many and varied examples by which this entirely revolutionary doctrine postulating a natural process of transmutation in the elements with the two heaviest atoms, could be brought to the test of crucial experiments.

This point is well illustrated by the decay and recovery curves. Fig. 26 shows the decay and recovery curves of Thorium X and Thorium (α-rays). Curve I shows the exponential decay of the radioactivity of Thorium X and curve II the recovery of the activity of thorium with lapse of time after separation. The initial parts for the first 24 hours show in I the simultaneous production by the Th X of the active deposit, before absent, and in II the decay of the active deposit in the thorium, at first present, in the absence of the parent thorium X. Also the recovery curve extrapolated backwards cuts the zero axis at about 25 per cent. of the final activity, due to thorium itself giving an α-activity nonseparable by any known process. The corresponding curves of Uranium X and Uranium (β-rays) (Fig. 27) show that decay and recovery proceed exponentially from the start, as there is no active deposit, or other active subsequent product, experimentally within the range of detection, and the β-rays furnish a direct measure of the quantity of uranium X.

This is how the theory of Rutherford and Soddy first arose that radioactivity is a consequence of atomic disintegration, the atom expelling charged particles as rays and changing into a somewhat lighter atom of a different element. At that time, the three disintegration series of uranium, radium and thorium appeared to run:—

$$\text{Uranium} \xrightarrow{\alpha} \underset{\text{22 days}}{\text{Uranium X}} \xrightarrow{\beta} ?$$

$$\text{Radium} \xrightarrow{\alpha} \underset{\text{4 days}}{\text{Radium Emanation}} \xrightarrow{\alpha}$$

$$\underset{\text{About 30 minutes}}{\text{Radium Active Deposit}} \xrightarrow{\alpha,\ \beta \text{ and } \gamma} ?$$

$$\text{Thorium} \xrightarrow{\alpha} \underset{\text{4 days}}{\text{Thorium X}} \xrightarrow{\alpha}$$

$$\underset{\text{1 minute}}{\text{Th. Emanation}} \xrightarrow{\alpha} \underset{\text{About 11 hours}}{\text{Th. Active Deposit}} \xrightarrow{\alpha,\ \beta \text{ and } \gamma} ?$$

The nature of the particle expelled in the change is shown above the arrows and the half-periods are given in the lower line. Overwhelming evidence of the correctness of this view began to accumulate on all sides, and the theory was completed in skeleton by 1902.

In due course, the naturally radioactive elements were found to belong to three long disintegration series, two starting from uranium, in one, radium and polonium, and, in the other, actinium being the best known of the intermediate members, and the other starting from thorium. The first comprises 14 successive but quite similar changes, the second 10, and the third 11.

THE THEORY OF RADIOACTIVE CHANGE.

As already stated in the previous part, radioactivity is a natural process quite incapable of being affected in its course to the slightest degree by any agency known before the end of the third decade of the present century. Its sum total is always preserved, and the easy apparent alterations brought about by physical and chemical agencies are due to alterations in the distribution of the numerous successive products. The process goes on exactly the same whether the latter are separated or not.

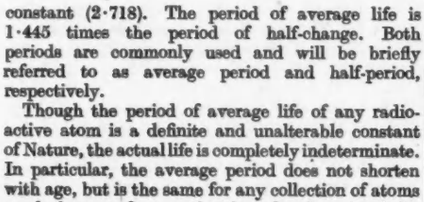
The law of change followed by any single radio-element is the same for all, and it is the simplest as well as the most inexplicable possible. It is the law of pure probability or chance. One can suppose a destroying angel, not selecting the atoms about to die, but at pure random picking on a certain proportion of those existing to break up in any given instant. This proportion is called the radioactive constant and usually symbolised by λ. It is proportional to the magnitude of the unit of time to which it refers, but, if not otherwise stated, the time unit of one second is to be assumed. Out of N atoms,

* We have arranged with Dr. Soddy to publish his new book, *The Story of Atomic Energy*, in the form of a series of articles which will appear at fortnightly intervals approximately. Dr. Soddy, however, retains the copyright, therefore no extract may be made from these articles without his permission.—ED. E.

λN break up per second, λ having a value characteristic for each kind of disintegrating atom. This assumes that λ is so small that the number left at the end of the second is not appreciably different from the number at the beginning, as is in most cases true. Then the period of average life of the atoms in seconds is the reciprocal of the radioactive constant, viz., $\frac{1}{\lambda}$. In this period the quantity is reduced to $\frac{1}{e}$, (0·368), where e is the exponential constant (2·718). The period of average life is 1·445 times the period of half-change. Both periods are commonly used and will be briefly referred to as average period and half-period, respectively.

Though the period of average life of any radio-active atom is a definite and unalterable constant of Nature, the actual life is completely indeterminate. In particular, the average period does not shorten with age, but is the same for any collection of atoms newly born as for one that has already existed for any former length of time. Thus this simple law defies explanation at present. It was well-known in chemical change, before radioactive change was known, but here the case is usually, if not always, due to quite different reasons which are easily understood.

Fig. 28.



FIGS. 28 AND 29. RUTHERFORD'S APPARATUS FOR DEMONSTRATING THE MAGNETIC DEVIATION OF α-RAYS.

HELIUM AND RADIOACTIVITY.

Now let us refer to something that literally came down to us from heaven to earth. In the year 1868, Lockyer observed in the spectrum of the sun a line known as D_3, very close to the yellow doublet D_1, D_2, given by sodium, corresponding to no known terrestrial element, and courageously named the solar element responsible for it, helium. No sooner was argon discovered than Professor Miers, the Oxford mineralogist, got into touch with Ramsay, who was then engaged in trying to make argon combine with other elements. He suggested to him that possibly a gas which Hillebrand, an American mineralogist and chemist, had found to be contained in uraninite (the primary mineral of which pitchblende is a secondary variety), and from chemical examination had concluded was nitrogen, might in fact be argon. It turned out to be helium! It proved to be the second lightest element known—of atomic weight 4 (on the oxygen = 16 scale which makes hydrogen 1·008).

Efforts to combine argon, and the other inert gases of the atmosphere, as they were discovered, continued fruitless; so what was helium doing *dans cet galère*? Ramsay and Travers had found that helium occurred only in the minerals containing uranium and the rare-earth elements, the latter usually containing thorium also. Since then, a new thorium-uranium mineral from Ceylon, thorianite, has been found to contain per gramme as much as 10 c.c. of helium. Since it is a very dense mineral, some nine times as dense as water, unless the helium is chemically combined in the mineral, the pressure necessary to compress the helium into the volume it occupies in the mineral would be some 90 atmospheres, even if the mineral itself were not already filling the space occupied. Simple considerations of this kind made it appear probable that helium was one of the ultimate products of the change of uranium and thorium. A negative result can sometimes be very informative.

THE AGE OF THE EARTH.

Similar reasoning by B. Boltwood, an American chemist, from the composition and geological age of the minerals in which uranium and thorium occur, some years later pointed correctly to lead being the other ultimate product of uranium and also that radium and actinium are produced by uranium. Conversely, nowadays, the ratio of uranium and/or thorium to lead or helium in minerals is a veritable "geological clock" giving their age directly, and some of the oldest are so found to have been in continuous existence for eighteen hundred million years. That assumes, of course, that the "clock" has been keeping even time throughout. The late Professor Joly, of Dublin, who, with the present Lord Rayleigh, was mainly responsible for this interesting development, thought the estimate much too high and that the clock had run faster in the past than now. After his death, he has been proved right, though on present knowledge the correction necessary is small and does not seriously invalidate this estimate of the age of the earth.

Fig. 29.

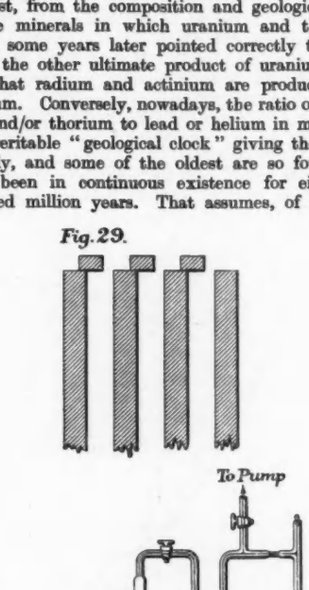


FIG. 31. APPARATUS FOR PROVING PRODUCTION OF HELIUM FROM RADIUM (RAMSAY AND SODDY).

THE ALPHA RAYS.

Let us now revert to the α-rays. At first taken to be a very "soft" (*i.e.*, non-penetrating) type of X-ray, this surmise very soon gave way to another and truly bound-breaking one, first suggested in 1900 by Mme. Curie for the rays of polonium, that they were really radiant material particles, just as the β-rays are radiant negative electrons, travelling with a speed some appreciable fraction of that of light itself. This would account both for their enormously greater energy and also for their very feeble penetrating power. Further, the general relations between electricity and matter were even then understood well enough to make it likely, as was first suggested by the present Lord Rayleigh in 1901, and by Sir William Crookes in 1902, that, if so, they should carry positive charges. As we put it now, it was thought they might be in fact "ions" or atoms of matter from which one or more negative electrons had been "knocked out" during the process of their ejection, or subsequent collision with the atoms in their path. The cathode-rays and β-rays had been relatively easy to identify as negative electrons because, the latter being very light, their trajectory is readily deflected, both by quite small magnets and by weak electric fields, though, in the latter case, the vacuum must be nearly perfect to avoid a masking effect due to ionisation, which baffled the first investigators.

Rutherford, with his great experimental gifts, made the α-rays he first discovered peculiarly his own subject; but it took him many laborious years of work fully to establish experimentally their real nature. The atom, being thousands of times heavier than the electron, is that much more difficult to deflect. Not only was a powerful electromagnet required but the very feeble penetrating power of the rays was a difficulty; also, he had to wait for a preparation of radium sufficiently active for the purpose. But he had succeeded, using ionisation methods, by 1902, in proving that the magnetic field deviates the trajectory of the α-particle into the arc of a circle of some 50 to a 100 times greater radius than for the cathode-ray, and in the opposite direction, showing that the charge is positive and that the mass, making certain assumptions, must at any rate be of the same order as that of the hydrogen atom. This was at once confirmed by Becquerel, using the photographic method and more active radium preparations, and both Rutherford and Des Coudres successfully extended it (1903) to the electric deviation, the two results indicating that, if the α-particle carried a single positive charge, its mass would be approximately 1·6 times that of the hydrogen atom. This assumed that the α-rays were homogeneous and of uniform velocity, which is not the case. Many other experiments were required in order definitely to determine the mass. Rutherford's apparatus for demonstrating the magnetic deviation of α-rays is illustrated diagrammatically in Figs. 28 and 29. The α-rays from radium passed through canalising slots in the magnetic field, which coiled their trajectories into arcs of circles, which he estimated to be of about 40 cm. radius, and so prevented them from entering the electroscope. The hydrogen gas lengthened the range of the α-rays, allowing them to traverse a longer path in the magnetic field and greatly increasing their ionisation effect relatively to the undeviable penetrating γ-radiation. Fig. 29 shows how, by half covering the openings of the slots, the direction of the deflection could be ascertained and shown to be opposite to that of the easily deviable β-rays. Fig. 30 is a reproduction of Mme. Curie's diagram showing the deviation of the three types of rays by a magnetic field at right angles to the plane of the paper. The opposite deviation of the α-rays to that of the easily deviated β-rays has been greatly exaggerated to show at all.

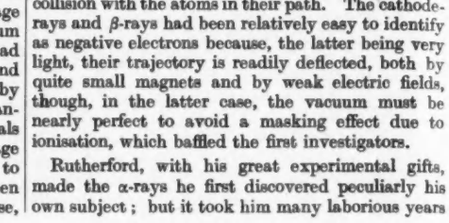


FIG. 30. DEVIATION OF BECQUEREL RAYS BY MAGNETIC FIELD (MME. CURIE).

Just as the cathode-rays were the vacuum-tube precursor of the β-rays, some previously known

"canal-rays" of the vacuum-tube are analogous to the α-rays. They were discovered by Goldstein, who used a perforated cathode and noticed that rays streamed through the perforations into the space behind the cathode. These were proved by Wien, in 1898, to consist of positively-charged ions, travelling at less than $\frac{1}{100}$th of the speed of light, with a variable $\frac{e}{m}$ ratio depending on the gas in the vacuum tube, but indicating a mass never less than that of the hydrogen ion. They are now usually called positive rays, and it is by such measurements as those of Wien that the modern method of determining the weight of the atoms as individuals depends. Hence the discoveries in this field have been very fruitful.

THE PRODUCTION OF HELIUM BY RADIUM.

In the meantime, the writer, who had left Montreal at the end of 1902, was at work with Sir William Ramsay in London, in the first place to obtain his endorsement of the conclusion that the emanations were argon gases. Walking one day early in 1903 along Mortimer Street, he saw an announcement in the shop-window of the firm of Messrs. Isenthal and Company, mainly electrical instrument dealers, that they had pure radium compounds on sale. It was the first consignment of what was by then already being commercially produced at the Chimiefabrik, in Brunswick, by Professor Giesel, and it was offered at the modest price of a few shillings per milligram of hydrated radium bromide, containing some 50 per cent. by weight of the pure element. That instantly altered the whole outlook. Till then it had not been possible to get preparations containing even $\frac{1}{10}$th per cent. But this made it feasible at once to put to the test whether the helium in uranium and thorium minerals had grown there in geological time, as all the evidence seemed so strongly to suggest.

At that time there was only one place in the world where that could be done. It was in Sir William Ramsay's laboratory in University College, London, where he and his able co-workers, notably M. W. Travers and E. C. C. Baly, in the course of the pursuit of the inert gases of the atmosphere, had developed a simple micro-technique for the handling and spectroscopic examination of small quantities of gases. There is only one part of xenon in twenty million of air, and all the investigations on it had been done with a small fraction of a cubic centimeter, worked upon over and over again without loss, then an unprecedented and unparalleled feat of gas-manipulation.

This problem, however, required the separation, purification and spectroscopic identification of much less than one ten-thousandth of a cubic centimetre of helium. This last is about the volume of a length of fine mercury-thermometer tube equal to the diameter of the bore. But 30 milligrams of the Isenthal manna sufficed to prove in a few weeks that radium was producing helium. With 50 milligrams of radium bromide in all, the growth of helium was followed from day to day in a sealed spectrum tube originally containing only radon, though it took all Sir William Ramsay's technique and skill as a glassblower to make one small enough. This was the first case of transmutation to be established by methods previously known. Fig. 31, opposite, shows the apparatus used by Ramsay and Soddy to prove the production of helium from radium. The radium bromide was put in the bulb A and dissolved by water in B, the whole having been previously exhausted of air. The hydrogen and oxygen were removed by a helical coil of red-hot oxidised-copper wire while the gas was in C, the water being absorbed by phosphorus pentoxide in D. When cold, mercury was allowed to enter from G, and E was cooled in liquid air to absorb carbon dioxide and radon. The gas was then allowed to enter the spectrum tube F, which is shown separately to a larger scale, on the right, in Fig. 31. This tube was found to give the helium spectrum.

The volume of pure radon available was only $\frac{1}{100000}$ths of a cubic centimetre, and by measuring this as accurately as possible, the first rough estimate of the minimum period of average life of radium was got, namely 1,150 years, instead of the true value 2,300 years, subsequently arrived at and already referred to. This experimental estimate of the minimum period of radium was got at about the same time as the calorimetric measurement, by P. Curie and Laborde, of the rate of energy liberation. So that, by 1903, or early in 1904, it had been proved that radioactivity is the accompaniment of an atomic disintegration, in which energy is released of the order of a million times that liberated in chemical changes, and that the process is proceeding fast enough in radium to allow the first product, radon, to be isolated as a new argon gas in measurable quantity, and its change to be followed with the spectroscope by the helium it produces.

(To be continued.)

LITERATURE.

Van Nostrand's Scientific Encyclopedia. Second edition. D. van Nostrand Company, Incorporated, 250, Fourth-avenue, New York 3, U.S.A. [Price 12 dols.]; and Macmillan and Company, Limited, St. Martin's-street, London, W.C.2. [Price 65*s.* net.]

THE endeavour to compress a whole scientific library into a single volume is an exacting task, almost inevitably liable to prove somewhat disappointing to compiler and reader alike even if the book runs to 1,600 large pages and weighs nearly 6 lb. The general editor has to decide what to leave out, and, however reasoned his judgment may be, omissions have an unhappy knack of being just what the reader wanted to look up, before his interest was mercifully distracted by some fascinating item of information on a totally different subject in an adjacent column. Such are the shortcomings of all encyclopædias. This one is open to more specific criticism in that the determination to be comprehensive has prompted the editors to include too many articles which are so brief as to be mere definitions, no more informative than those of a good dictionary. All such items, as well as many other rather longer descriptions of subjects that are likely to be familiar, or at least readily accessible in other works of reference, occupy space that, with greater advantage than mere comprehensiveness, might have been added to articles on outstanding new scientific developments or on matters of fundamental importance, all of which are necessarily far from completely satisfying.

By the same line of argument, it is not easy to justify the attempt to include so vast a subject as medicine among 20 branches of science that are predominantly concerned with mechanical physics in the broad sense of that term. Admittedly, botany and zoology are proper subjects for a scientific encyclopædia, and from them the steps to human anatomy, physiology, disease and its treatment follow easily and naturally. Equally, however, do those to a dozen other sciences in which a little learning may be much less dangerous, and which lend themselves better to precise methods of analysis than does therapeutic medicine. Rather unexpectedly, also, the compilers have paid scant attention to the scientific apparatus used in medical diagnosis and treatment, or the adaptations of medical technology for research in physics and engineering.

Apart from these major criticisms, the only adverse comments from British readers are likely to arise from the exclusively American authorship of the encyclopædia, which has resulted in a general tendency to draw on American sources for examples and illustrations, and to show less than due appreciation of several outstanding British contributions to mechanical science. The article on the jet engine, for instance, does not even mention the name of Air-Commodore Whittle. It is fair to add, however, that the text consistently tends to omit biographical matter, partly, no doubt, in order to avoid controversy. In almost every other respect, the encyclopædia is a thoroughly reliable and painstaking piece of work. This second edition follows generally the scope and pattern of the first edition, published in 1938, but the sections dealing with electronics, metallurgy, meteorology, photography and statistics are newly added, while those on aeronautics, engineering and navigation have been expanded and brought up to date as far as possible. In addition to the subjects already mentioned, astronomy, chemistry, geology, mineralogy and physics make up the total of 20 divisions of science, which are dealt with in over 11,000 topics, arranged alphabetically. Extensive cross-referencing is achieved with admirable simplicity by printing in bold type the individual words under which related information is to be found. Despite occasional instances of overlapping, not invariably free from minor disparities in factual information, the writing and editing have been carried out with scrupulous care, while the printing, illustration and production of the book are of a correspondingly high standard. It is, in fact, a fine piece of work, well deserving the title of encyclopædia.

Notes Introductory to the Theory and Design of Gas Turbines. By PROFESSOR JAMES SMALL, D.Sc., Ph.D. Published by the author at the James Watt Engineering Laboratories, University of Glasgow. [Price 7*s.* 6*d.* net.]

THIS little book represents a type of publication wholly to be desired. In the range of publications from an article in a technical journal or a paper to an engineering institution, on the one hand, to a comprehensive book, on the other, there is often, in this country, a serious gap; many specialists who have not the time to write a large book, if they were persuaded to set down their special experience in a compact form, would produce monographs of high value. The present work, based on six lectures delivered by the author, gives a valuable survey of its subject. The presentation, including the diagrams, is good; and the fundamentals are set out clearly and explained in a straightforward manner. While there is little that will be new to the relatively small number of engineers who are concerned intimately with gas-turbine design, for the very much larger number in cognate branches, who wish to understand the basis of this relatively new development, the treatment is admirable. Such readers do not need to have the ground work of thermodynamics repeated for them at length, but wish to restrict themselves to essentials.

Certain small criticisms may be offered for consideration if further editions are called for. Professor Small, in his preface, gives the impression that he does not intend to give references to published papers, though he goes against this indication in three instances; but he might consider the provision of a bibliography of important papers, if only in fairness to authors whose work is not acknowledged. The question of the actual specific heats and the adiabatic index of gases might be more clearly explained; for example, the author makes many calculations with the value 1·4 for the index and then mentions, without explanation, that the value taken for expansion in the turbine in aircraft-engine practice is 1·33. As regards combustion chambers, it would appear a little unjust to Air Commodore Whittle to suggest that his name is associated only with designs in which the gases are caused to reverse their direction of flow before entering the turbine. While this was the arrangement in the early Whittle engines, due account should be taken of the subsequent collaboration of Whittle with those engine builders who benefited from his early experiences. In the reference to the closed-circuit design of Escher Wyss, Dr. Small might have mentioned, in connection with the control, the high efficiencies measured by Professor Quiby at reduced loads, at constant speed, on this turbine: 29·5 per cent. at half-load, compared with 31·5 per cent. at full load. The author gives a proposed marine installation with separate low-pressure turbines for ahead and astern running, respectively, presumably following that in a paper to the Institute of Marine Engineers; in the latter, however, arrangements were also shown for exhausting the casing of the idle turbine, a provision left out by the author. In discussing the compounding of compression and expansion, it is stated that compounding gives no increase to the efficiency of the cycle unless in conjunction with exhaust-heat recovery; this is not correct, however, since improvements, both to efficiency and output per pound of air, follow simply from applying compounding and intercooling to compression in the simple open installation. It is always an advantage

in both respects to reduce the work of compression as much as possible. In an interesting set of typical calculations the author has chosen, as an example, one of the original Whittle engines, without giving any reasons for his choice; while this does not reduce the value of the example, a somewhat later design would have been preferable. These comments are relatively minor ones, however, and do not affect the commendation that may be offered without reserve to the author for his valuable contribution to the literature of gas turbines.

The Principles of Technical Electricity. By M. NELKON, M.Sc., A.K.C. Blackie and Son, Limited, 66, Chandos-place, Strand, London, W.C.2. [Price 17*s.* 6*d.* net.]

IN the teaching of physics, especially to engineering students, there must frequently be some difficulty in determining to what extent it is desirable to devote attention to modern electronic theory. Text-books based on classical physics, which usually approached their subject through the cat's skin and the stick of sealing wax, passing from static to what they called voltaic electricity, were, in general, concerned with the properties of electric currents and charges, not with their nature. The teaching they imparted was of practical application and formed an adequate basis for the design of most types of electrical machines. Modern theory, based on the properties of the electron, has reduced all electrical phenomena more or less to a common basis, but a thorough study of the subject may demand more time than many engineering students can justifiably afford. The developments of practice in recent years, however, have made at least a basic understanding of the constitution of matter and the properties of the free electron of direct practical importance to engineers engaged in a wide and growing branch of electrical engineering. It is not only those concerned with radio work who are affected; electronic devices are rapidly increasing in their range of application and it is desirable that those who may have to utilise them should have an understanding of their properties.

This admirable book provides an approach to practical electrical-engineering problems based directly on modern theories of matter. The student is introduced to electrons, protons and ions in the first six lines and the fundamental point of view is maintained throughout the treatment of direct- and alternating-current theory, electrostatics, electromagnetic induction and the other branches of work on which it touches. It is not concerned with the details of practical application and, for instance, in the section dealing with the heating effects of an electric current, while it is shown that the efficiency of an accumulator is high because its internal resistance is low, no description of actual accumulators is given. Throughout, however, when necessary, sufficient information about the main features of plant and apparatus is included to elucidate the theoretical argument. This applies to the final chapter, which deals with the basic principles of diode and triode valves and the cathode-ray tube. The contents of this particular chapter form a good example of the type of information and instruction with which, under modern conditions, it is desirable that all electrical-engineering students should be furnished. The standard of the book represents approximately that adopted in the City and Guilds Technical Electricity Examinations. The mathematics is relatively simple.

"ELECTROPLATING."—The first number of *Electroplating*, a new monthly periodical dealing exclusively with the science and practice of metal-finishing, has been issued. The publication is intended for the user and producer of modern metal-finishing processes, such as anodising, enamelling, lacquering, bronzing, polishing and phosphating, as well as electroplating. The first issue contains a well-written article on the fundamental principles and technique of the study of the microstructure of electroplated surfaces, by Dr. A. T. Steer, of the Rover Company, Limited, Birmingham. Other articles deal with electrolytic polishing, the third International Conference on Electrodeposition held in London in September, copper plating on steel with a cyanide-free electrolyte, and other matters. The journal measures 5¼ in. by 8½ in., and is attractively prepared and well printed. The editor and publisher is Mr. C. R. Draper, A.I.M., F.C.S., 83, Udney Park-road, Teddington, Middlesex.

BRITTLE FRACTURE IN MILD-STEEL PLATES—I.

(*Continued from page* 534.)

WE continue below the report of the Conference on "Brittle Fracture in Mild-Steel Plates," by reprinting the contribution of Mr. J. L. Adam, C.B.E., Chief Surveyor of the British Corporation Register of Shipping and Aircraft. Mr. Adam's paper was actually the third item in the programme of the Conference, having been preceded by the paper on "Brittle Fracture of Mild-Steel Plates," by Dr. C. F. Tipper. Dr. Tipper's paper will be reprinted later.

BRITTLENESS IN SHIP STEEL.

Mr. J. L. Adam, in presenting his paper, said: My report describes what I have seen during a long experience in the use of ship steel. I am quite prepared to be told that a form of brittleness found in one case has nothing to do with the brittleness encountered in some other case. The fact remains, however, that, whether in one form or another, the shipbuilder has suffered from it for the past 40 years, and has called it brittleness. The fractures shown in my diagrams are only the fractures of which I have personal knowledge, and I have no doubt that reports from America would add greatly to the value of the diagrams. It so happens that, while we get examples of every one of those fractures in all-welded ships and in ships which have riveted frames but are otherwise all welded, we do not (so far as our reports show) get all those types of fracture where we rivet the longitudinal seams. With the last-mentioned type of construction, any fracture which threatened failure of the structure has been from a definite notch, and more or less explainable.

What worries us from the point of view of the development of ships' structures is that brittle steels have been used in riveted ships without many failures during the past 40 years. We do get the effect of brittle failure, after some years of service, at definite spots where it is easily understood, but in riveted ships we have not had failures of the order shown in the diagram, and that rather complicates the problem of ship structural design. My opinion is that our troubles in the welded ship are due to three causes, namely, design, the use of welding as opposed to riveting, and the fact that the nature of the material is more important in welded structures (as they have so far been designed and built) than in riveted structures. Brittleness in steel used for shipbuilding is not new in our experience; my own experience of it extends over 40 years, when I remember that it was common practice to "fire" plates on cold, frosty winter mornings to prevent cracking between rivet holes and between rivet holes and the edges, during punching. We built the ships, however, and with few exceptions—there were exceptions—had no trouble with them in service.

Immediately after the last war, we again had an outcry about brittle material and, in this case, practically all of it came from America. This material was badly segregated, had many laminations, both on the surface and internally and, in some cases, proved very defective when being worked in the shipyard. Yet America built many ships about that time and many of them are afloat to-day and giving no great trouble. It is true, however, that numerous renewals have been carried out, but largely on account of excessive corrosion and erosion. There have been only a few instances of cracking in service.

About the middle 'twenties, we again had an outcry regarding defective steel, of Continental origin. This was badly segregated steel which showed many defects in service and often called for renewal within a few years due to large portions of the material over considerable areas disintegrating—I can think of no better word. A certain amount of brittleness was experienced in working those plates, but very little trouble was experienced from brittleness in service. All those ships were riveted and the construction followed normal procedure.

The question of brittleness in steel has revived because of the occurrences in a large number of American ships. The failures have been much more alarming and are of much more frequent occurrence than anything that has been experienced in shipbuilding history. Despite the efforts made in this country and in the United States, and the immense amount of data collected, it is not possible to give a clear answer to all the questions which arise.

To illustrate, however, that the problem is to-day an urgent one, I submit the diagram, Fig. 1, opposite, which illustrates the types of cracks that are found in American ships of one type. They are illustrative of occurrences which have actually been dealt with by myself and my colleagues in this country—in other words, the diagram represents first-hand information. There are some 3,000 ships and about 4 per cent. of them have developed cracks of the major order; that is to say, fractures which would lead to total failure of the structure. It is not suggested that the fractures illustrated in the diagram are all found in one ship, but some of the fractures are by themselves quite sufficient to cause complete failure of the structure.

These fractures are roughly of three classes. First, there are those due to defective detail in design, such as are marked "A" in the diagram, but do not spread into the surrounding material. These fractures, I think, may be neglected by this gathering because I am sure, in my own mind, that they would have occurred, with the form of corner construction adopted, in any ship of the type whether riveted or welded, or whether made of ductile or brittle material.

Fractures of the order of "B" probably started at the corners, but travelled across the deck and frequently down the sides. It has been found that the crack, once started, will travel across material which shows no evidence of undue brittleness.

The "C" type of crack is in rather a different category, as there is evidence to show that it may start at the inboard end and travel outwards. It did not travel down the side. Unfortunately, we have no evidence to show whether the plate in which this type of crack started was brittle, because the repairs to the ship were carried out by drilling a hole at the end of the crack, veeing out the crack and re-welding, and so there was no material available for testing. A piece of plate in the strake of plating marked X was cut out because the fracture came so close to the butt; this plate had Izod values of about 10 to 15 at room temperature. Quite a number of repairs of this order have been carried out, and there has been no subsequent failure.

Fractures of the "D" type are sometimes localised at the corner of the deckhouse, but sometimes spread, as shown by the different illustrations. Again, it is difficult to be definite as to whether this is due to brittleness of material or incidental to welding practice. It is suggested that in the cases where they have spread, there is brittle material and in one particular case the material was brittle.

"E" fractures are typical of many instances and, in all the cases of which full particulars are available, the material has been of a brittle nature by comparison with ordinary good British steel. Such fractures call for immediate measures, as they would lead inevitably to the failure of the structure.

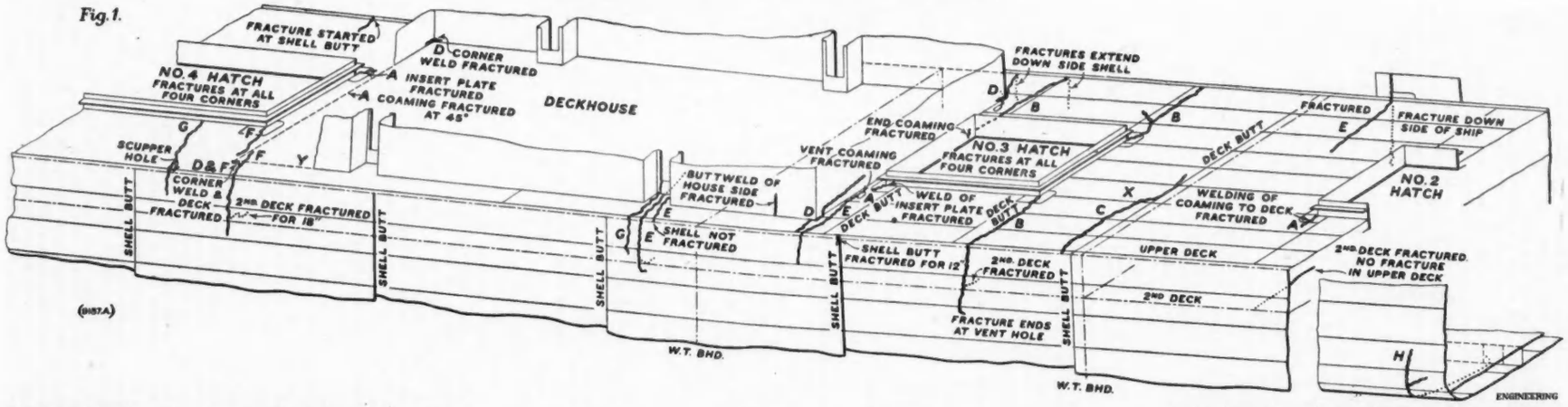
A number of very interesting failures are those marked "F." For instance, the failures in the neighbourhood of the forward end of No. 4 hatch show that, in one ship, two cracks started, one from the corner of the hatchway, which travelled out about 8 ft., and another extending inboard from the junction of the deck and sheerstrake for about 12 ft., and for 5 ft. or 6 ft. running parallel within a short distance of the other crack. In this case, the material from the intermediate strake of plating (Y) was tested and found to be of a brittle nature. The cracks elsewhere were repaired by drilling holes at the ends, veeing out and welding, and no further trouble has arisen.

The "G" type of crack starts from a notch—quite a small notch—and spreads in two directions, one vertical and one inboard. Although there have been quite a number of cracks of this nature, we have no evidence to show whether or not the material was exceptionally brittle.

Cracks of the type illustrated by "H" have been found in a number of ships, and samples of material have, in some cases, shown brittle charac-

BRITTLENESS IN SHIP STEEL.

Fig. 1.



teristics. In other cases, however, the test results of the material have shown a very low tensile strength even if the Izod values were quite good.

It will be seen that the problem to-day is much more acute than it ever has been and, of course, circumstances are very different. Figs. 2 to 6, herewith, show why it is difficult for us, as ship structural designers, to give a clear picture. Fig. 2 illustrates the type of ship under discussion as it would have been built prior to the introduction of welding on a large scale. Experience, and the evidence, suggests that, even with the material which has been incorporated in these ships, we would not likely have had major fractures in service, although we might have had a fairly large repair bill as the years went by. Fig. 4 shows the 100-per cent. welded ship of the same type, as built in the United States. In this ship, all the types of fractures illustrated in the diagram have been found.

Fig. 4 illustrates the ship which has been all-welded, but with the frames on the sides riveted. Again, all the types of fractures illustrated in Fig. 1 have been found in such ships. Fig. 5 illustrates the same ship, but in this case all the structure is welded except the horizontal seams of the side plating. In the case of these ships, there have only been two instances of fractures which might be described as major fractures, and these are doubtful because of the notch effect illustrated by type "G," described earlier. Short corner cracks appeared, but these can be neglected. No fractures of the order "H" have been found in such ships. It is true that all these ships, some 300 of them, were built in the one yard and that they are the only yard adopting this practice. It is true also that no cases have been found of excessive brittleness in the material used in the construction of these ships, although there have been cases where the material was very badly segregated and of low

Fig. 2. Fig. 3. Fig. 4. Fig. 5. Fig. 6.

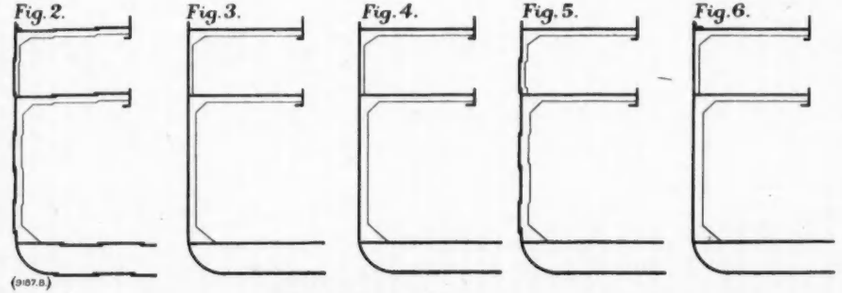
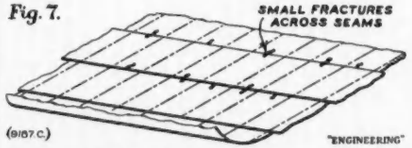


Fig. 7.



tensile strength, but had relatively good Izod values at normal room temperatures.

Fig. 6 illustrates the same ship, but with the introduction of a riveted gunwale angle; that is, a riveted connection between the deck and the vertical plating. Experience has shown that this has relieved the major cracking on the top side, but has not prevented cracks of the order of "H" in the bottom. The arrangement has, however, only been adopted in conjunction with improved hatch corners. All these ships other than Fig. 2 have been built in large pre-fabricated sections; sometimes the fitting of the berths was not too good and a considerable amount of brute force had to be exerted to make the joints "marry."

From the point of view of a ship structural designer, I am not able to form a definite opinion whether failure is mainly due to a disposition of material which is quite satisfactory with an all-riveted structure but needs modification for an all-welded structure, or whether the disposition of material is quite satisfactory even for the welded structure; but the introduction of welding has shown that the material which must be used in future will require definite non-brittle characteristics. At the present moment, my experience would seem to indicate that both the kind of material, and prefabrication, are contributory factors, but that the nature of material is of much greater importance than in the case of the all-riveted ship.

Fig. 7, herewith, illustrates fractures which occurred during construction. In this case, the bottom plating was laid out on the berths in the open and the seams were Unionmelt-welded during winter, when the temperature was below zero at times. Some 40 little cracks of the order shown appeared on cooling the material, and the material itself was found to be of a pronounced rimming type.

I have tried to make it obvious why we who are interested in ships' structures have called on the scientists to investigate this problem and provide us with a steel at economical cost in which we can have confidence when building welded ships. We know that the steelmakers can provide us with steel which serves all purposes, but we wish to know how we are to be assured that we shall always get this steel under commercial conditions. We know that we can carry out tests which will show whether the material is or is not brittle, but that is "locking the stable door after the horse is stolen."

(To be continued.)

KENWARD MEMORIAL RESEARCH FELLOWSHIP.—A research fellowship in industrial administration is to be founded at St. Catherine's College, Cambridge, as a memorial to Sir Harold Kenward, director of distribution of the Dunlop Rubber Company, Limited, who died on board the Queen Elizabeth, on August 28, 1947, while on his way to the United States. The trustees of the fellowship are Sir Miles Thomas, who succeeded Sir Harold as President of the Society of Motor Manufacturers and Traders, Sir George Beharrell, chairman of the Dunlop Company, Sir Reginald Rootes, Mr. C. E. Wallis and Mr. K. C. Johnson-Davies. An appeal for 25,000*l.* is being made to found the memorial.

INSTITUTION OF CIVIL ENGINEERS CHRISTMAS LECTURES.—Owing to the success of the lectures on railways delivered at the Institution of Civil Engineers last Christmas, a series of three lectures on "High-Speed Flying and the Airport" has been arranged at the Institution this Christmas. The lectures are intended primarily for boys between the ages of 13 and 17 years. The first, on "High-Speed Flying," by Group Captain E. M. Donaldson, D.S.O., A.F.C., will be delivered at 3 p.m., on Tuesday, December 30. The second lecture, on "The Airport: How it is Built," will be given by Mr. C. E. Foster, C.B.E., A.M.I.C.E., at 3 p.m., on Friday, January 2, 1948, and the third, on "The Airport: How it is Run," will be delivered by Sir John D'Albiac, K.B.E., C.B., D.S.O., at 3 p.m., on Tuesday, January 6, 1948. Tickets can be obtained from the secretary of the Institution, Great George-street, London, S.W.1.

STANDARDISATION OF POWER CABLES.*

By W. H. LYTHGOE, M.I.E.E.

THE first British standard specification for insulated cables was drafted in 1904 by the Engineering Standards Committee and dealt with paper-, rubber- and jute-insulated cables. Since that date, 19 specifications have been issued, of which nine are still current. Modifications of some existing specifications are in hand, and it is probable that revisions of those for ship's cables and cable sheathings will be issued in due course. At present, cable standardisation is unnecessarily wide; in fact, most of the existing ranges appear to be more than sufficient for the requirements of modern electrical systems. An attempt has been made, however, in the latest issues of some specifications for paper and varnished-cambric cables to bring the number of alternative sizes and types more into line with the actual requirements of the industry. In the author's opinion, the amount of progress effected in this direction still falls short of the ideal. A further point, to which future consideration might be given, is to differentiate between primary and secondary sizes, so as to ensure that in all cases the minimum number of sizes and types are adopted for any application. This would have the advantage, not only of limiting the number of alternative cables employed, but of reducing the fittings and simplifying the terminating equipment necessary for transformers, switchgear and motors.

Since the publication of B.S. 480-1933, the mean thickness of the insulation and lead on rubber and thermoplastic cables has been specified, while in the case of paper, varnished-cambric and jute cables minimum values are used. The object of both methods is to ensure that the thickness of material in the finished cable complies with the specified figure, and to provide both manufacturer and user with a ready means of checking. The thickness of beddings and servings for all types must comply with the specified values, although the manufacturer can probably exercise less efficient control of these items than of either insulation or sheaths, and they are certainly of less importance. The advocates of both the "mean" and "minimum" definitions each advance arguments which seem to them to be good and sufficient to justify their favourite method. Until 1933, however, the specifications required all insulation and lead thicknesses to comply with the stipulation that the mean of measurements round the circumference should be not less than the specified figure and that any individual measurement should not be less than 90 per cent. of it. The existing alternatives, therefore, do not seem to be justified, while the objection to the "minimum" definition is that the cable is always larger than the standard by the amount of the manufacturing tolerances considered necessary by the individual maker.

Standardisation can be based on two alternative general principles: to include in the standards a full range of all sizes and types likely to be required or to test selected primary and secondary standards. The advantage of the second alternative is that the potential user is shown what sizes and types are in most general demand and is therefore able to select, wherever possible, primary standards which he knows should be readily available. Manufacturers' stocks would thus be simplified and delivery improved. The present British standards for cables are not generally based on this principle. As a result, sizes are chosen only by taking into account considerations of current rating to voltage drop, thereby creating an artificial diversity of demand, which is the antithesis of progressive standardisation. The advantages to be gained by the introduction of primary and secondary standards for all types would be a reduction in labour and overhead charges. The former includes the cost of loading and setting up the machines, the cost of operating the length itself, and the cost of unloading the machines. These would perhaps be negligible if long lengths of the same cable could be manufactured consecutively. Unfortunately, under the present system of standards this is not the case. Examination of manufacturing records shows that the average order for power cable is for little more than a quarter mile in length. This indicates the advantages to be gained if demand could be centred on a more restricted number of sizes and types.

At present there are nearly 2,500 standard sizes and types of cable, while earlier the total was a little over 3,200. Apart from the tough rubber-sheathed and braided vulcanised rubber or thermoplastic insulated cables, nearly all specifications permit as alternative finishes lead-covered, lead-covered and served, steel-tape-armoured and served, single-wire armoured and served, single-wire armoured left bright and double-wire armoured and served. When these variations are taken into account the number of different standard types which a manufacturer may be called upon to produce, is of the order of 15,000 to 18,000. These figures ignore special constructions, which may be dictated by installations requiring unusual types of cable or protection, and cables not yet included in the official standards. The problems of reviving the export trade of this country are of major interest at the present time. Several countries, which before the war did not produce their own cables, are to-day more self-sufficient. Our attempt to increase export business will be defeated unless we can cut our manufacturing costs to a minimum consistent with the maintenance of the quality which for so long has been recognised abroad as the hallmark of British goods. For this reason alone, a detailed survey of standards should be worth while.

As regards normal stranded conductors, there appear to be sound reasons why the same range of primary sizes should be standardised for all the main classes of dielectric in common use. Clearly, future standardisation can be met by the adoption of primary standards for the sizes in general use, together with a reasonable range of secondary sizes to deal with more special cases. In 1919, an attempt was made to limit the number of alternative wire sizes and to standardise a range of sizes which could be built up conveniently from their wire diameters. The fact that this system has persisted for over 20 years is sufficient indication that the basis on which it was drafted is sound and convenient to user and manufacturer alike. It is common practice, from the point of view of both convenience and electrical stress, to make the minimum size of conductor 0·007 sq. in. for 660-volt power cables and 0·0225 sq. in. for voltages up to 11 kV. At still higher voltages electrical stress is the overriding consideration. Further, the higher working pressures are adopted only where the load involved or the distance it has to be transmitted is considerable and small sectional areas are uneconomic. The minimum size adopted for 22-kV transmission in this country is 0·04 sq. in., and it is probable that nothing less than 0·06 sq. in. will be standardised for 33 kV. With regard to maximum sizes, manufacturers experience very little demand for multi-core low-voltage cables above 0·5 sq. in. For still higher voltages, sizes in excess of 0·3 sq. in. are not in frequent demand. It is therefore suggested that the maximum primary standard should be 0·3 sq. in. for multi-core cable for voltages up to 22 kV, while the minimum primary standards should be 0·0225 sq. in. for voltages up to 11 kV and 0·04 sq. in. for 22 kV. The maximum secondary standard for the same range of voltages should be 0·5 sq. in., and the minimum standards 0·1, 0·0225 and 0·04 sq. in. for voltages of 660 volts, 3·3 kV to 11 kV, and 22 kV, respectively. The minimum primary and secondary standards for single-core cable should be the same as those for multi-core cables, while the maximum primary standard should be 0·75 sq. in. for 660-volt cables and 0·5 sq. in. for cables operating at higher voltages up to 22 kV. The maximum secondary standards should be 1·0 sq. in. for 660-volt cables and 0·75 sq. in. for cables operating at voltages up to 22 kV.

To determine the range of conductor sizes to be standardised within these limits the knowledge gained from the work of the Electrical Research Association on the ratings of all types of cable should be utilised. The ratings of any range of cable of the same type operating under similar conditions often lie substantially on a straight-line curve when plotted on log-log scales. It is, therefore, suggested that the range of standard sizes should be selected with a view to giving fairly even spacing on such a curve, since by so doing the sizes correspond to evenly-spaced increments of cable rating and the standards are linked logically with cable performance. The sizes chosen, however, should not require an unnecessarily large number of individual wire sizes in the make-up of the strand. In this way the present range of standards could be reduced from 17 to 10, and only five instead of 10 individual wire sizes would be required.

The stiffness of the conductor has a marked bearing on flexibility and, for cables where this property is of particular importance, careful selection of wire size and lengths of lay is necessary. In 1926, 28 sizes of flexible conductor were standardised, 12 of which were for trailing cables and similar purposes. At the present time there is a total of 31 possibilities. Moreover, in most cases two, or sometimes three, choices of individual wire diameter are allowed, depending on the purpose for which the cable is to be used. For maximum economy in manufacture the largest wire diameter consistent with the degree of flexibility desired should be used. Small diameters are uneconomic in relation to the larger. For instance, the amount of work required in making a wire for a flexible strand with 0·0076-in. diameter wires instead of 0·029 in. is in the ratio of 150 to 1, without allowing for the stranding operation. There has been an appreciable increase in the range of standard flexible conductors since 1926, to reduce which the same principle should be applied as for normal stranded conductors.

Before 1936, no serious attempt has been made to distinguish between applications of the same type of dielectric for different purposes, all prior standards having been broadly considered from the point of view of their general application to transmission and distribution as a whole. In that year, however, the issue of B.S. 708 for rubber-insulated trailing cables for mining work indicated a change in trend, while in 1938, B.S. 760 was issued for paper-insulated cables for mining purposes and B.S. 883 for rubber-, paper- and varnished-cambric cables for ships. The increase in the number of these special standards for specific applications is an argument for consideration being given to their scope, so as to ensure that the number of alternatives permitted is kept to a minimum. If this is not done the tendency will be for the cable industry to be saddled with an unnecessary multiplicity of sizes, types and alternative constructions, to an extent which will reduce the possibility of economic production to a low level. At the same time, it is suggested that the scope of the present standards is inadequate for modern requirements. For example, 33-kV paper-insulated cables for transmission and distribution purposes have now reached a stage at which it would be proper to include them in the British standards, and it seems likely that other types and constructions of cable will be added in due course.

The first issue of B.S. 7 in 1904, for paper-insulated cables covered a range of voltages up to 11 kV. The thickness of the insulation was reduced in 1919 as a result of improvements in manufacturing technique and in quality of material. Further reductions were made in 1933, when the scope of the standards was extended to 22-kV. It is interesting to note that, in the latter year, it was found possible to standardise a thickness of dielectric for 22-kV cable slightly less than that recommended between 1904 and 1919 for a working voltage of 11 kV. From 1904 onwards, it was customary to increase the dielectric thickness for the larger size of 660-volt cables. The reason for this was mechanical rather than electrical and the principle is sound. It is not so necessary for higher voltages. Until 1933 it was customary to maintain the same thickness of dielectric, irrespective of the size of the conductor, in all standard cables for working voltages from 2·2-kV to 11-kV, inclusive. With the issue of B.S. 480-1933 this practice was changed, and for sizes of conductor in excess of 0·3 sq. in. the thickness of the dielectric was increased with the size. Since the tendency in super-voltage cables is now to design largely on an electrical-stress basis, giving decreasing dielectric thickness with increased size of conductor, the present practice for 2·2-kV to 11-kV cables needs reconsideration. There seems no justification for variation of thickness with conductor size from 3·3 kV to 22 kV, and in any further review of the present standards this point should be given attention. Constant thickness can be adopted quite reasonably for all these voltages and it is possible that with further experience the principle of designing cables on electric stress will extend downward to 33-kV, or even lower working voltages.

Since the standards for rubber-insulated cables were published in 1904, there have been significant changes in dielectric construction. No alteration has been made, however, in the radial thickness for low-voltage rubber cables, while at the highest voltage included, namely 11 kV, the only change has been the replacement of a variation of thickness from 0·29 in. to 0·31 in. by a uniform standard of 0·3 in. for all sizes. Bearing in mind that the majority of rubber-insulated cables are made in relatively small sizes, and that most thin dielectrics are applied by longitudinal covering rather than lapping, it is surprising that the simpler processing and calendering obtained by the use of more uniform thicknesses have not encouraged some modification of rubber cable dielectrics in the past 43 years. It is logical that for low-voltage cables the dielectric thickness should be greater on the larger sizes for mechanical reasons, yet the present practice of using a different thickness of rubber for every size appears to be both unnecessary and uneconomic. This point has been emphasised recently by the considerable substitution of 250-volt varnished-cambric cables for rubber during the war, especially for ship use. The service record of these cables has been good and the insulation thicknesses, both for 250 and 660 volts, are much below those for rubber. There seems scope, therefore, for some reconsideration of rubber-insulation thicknesses.

Varnished-cambric cables are not employed extensively for distributors or feeders, but are useful for special applications. Their maximum operating temperature is assumed to be higher than that of rubber-insulated cables and about equal to that of the corresponding paper cables. As the thermal resistivity and power factor of varnished cambric are higher than those for impregnated paper, the ratings at higher voltages are somewhat lower than for paper. Consequently, the voltage range for which varnished cambric is suitable is somewhat restricted, and the present British standards do not legislate for voltages above 11 kV. The demand for varnished cambric will probably

* Paper read before the Transmission Section of the Institution of Electrical Engineers on Wednesday, November 12, 1947. Abridged.

continue to be small compared with that for paper cables. Nevertheless, within the voltage range covering both types, as many alternatives are included for varnished-cambric cables as for paper. Actually, there are more, because varnished-cambric cables can be supplied with a taped and braided finish, as well as lead covered. Future standards can, therefore, be drastically reduced in number. The existing voltage range is ample for normal requirements.

Thermoplastic insulation was first standardised in 1943, cables so insulated and/or sheathed being adopted as permissible alternatives to rubber cables and flexible cords for 250-volt and 660-volt systems up to a maximum of 0·06 sq. in. The effect of this apparently minor change has yet to be foreseen, and great vigilance is therefore required to ensure that the standards for this relative newcomer in the insulation field are maintained within reasonable bounds. The start has not been propitious, as the insulation thicknesses allowed are equal to, or greater than, the corresponding rubber thicknesses at both 250 volts and 660 volts. The comparable rubber dielectrics are applied in layers, either by longitudinal covering or lapping, whereas polyvinyl chloride is extruded. While extruded thicknesses may not be so readily controllable at present as longitudinally applied or lapped insulation, therefore justifying some increase in the radial value, there seems to be little reason to saddle polyvinyl-chloride construction with the varied range of thicknesses still employed for rubber. It seems reasonable to inquire whether for this entirely new dielectric there has been adequate investigation of the physical dimensions and test performances to prove the necessity of the present apparent complications. The suggested review of rubber dielectric thickness could be extended with advantage to include polyvinyl chloride.

The thicknesses of lead sheaths for power cables are based on the cable diameter under the lead and have not changed materially during the period under review. Because of the different installation conditions of rubber-insulated cables, on the one hand, and paper and varnished-cambric cables on the other, three types of sheathing became popular; lead containing 2 per cent. tin was standardised for rubber-insulated cables, while for paper and varnished-cambric cables commercially pure lead became standard, except for cables known to be subject to vibration, where an alloy containing 0·85 per cent. antimony was used. As a result of the shortages of raw materials and rarer metals, especially cadmium, during the war, a new general-purpose alloy containing 0·4 per cent. tin and 0·2 per cent. antimony was standardised and has been found satisfactory to manufacturer and user alike. The indications are that it will become a useful general-purpose alloy where vibration is encountered and that it is likely to replace most of the alloys previously standardised. If, as a result of further development work, a position is reached where one, or possibly two, alloys can be adopted to meet all normal vibration conditions, production will be more economic.

So far, with one exception, there has been no tendency in British standards to define the exact construction of beddings and servings, but merely to specify the total thickness to be obtained. An examination of current specifications shows that, for paper and varnished-cambric insulated cable, 0·1 in. thickness of bedding and serving is adopted for all sizes, except in ship-wiring cables. Rubber cables, on the other hand, have graded thicknesses of beddings. For their protection, overall braiding is adopted up to 0·75 in. diameter over the lead and constant thickness of serving for all larger diameters, except for ship wiring, for which overall braiding is used exclusively. It seems logical to suggest that varnished-cambric cables should in future follow the practice adopted for rubber cables, since their normal conditions of use approximate more closely to those of rubber cables than of paper cables. The alternatives of serving and braiding for paper cables in mines will probably continue, as, although the braided finish appears to be more suitable for wiring work, the additional cost and delay in production may not always be justified. As regards armouring, the distinctions in size for the same cable diameter made in earlier years between single and double-wire armoured cables have been eliminated and the number of wire diameters has been reduced. There has also been a tendency for the size of the wire to be reduced somewhat in comparison with the diameter of the cable to which it is applied.

If it be conceded that a comprehensive review of the specifications for general-purpose cables is justified, there is surely an even greater need for adequate checks on the special-purpose types, since, owing to the simpler issues involved, a greater degree of standardisation should be possible. The specification for paper-insulated mining cables (B.S. 760) is a particularly obvious case. Owing to the need for the greatest possible safety in mines and the onerous conditions involved, the thickness of insulation, and consequently the whole cable construction, is heavier than normal. In spite of the obvious opportunities for simplification, the mining standards cover just as many alternative constructions as the specification (B.S. 480) which deals with all the requirements of electricity supply and distribution. It is also doubtful whether all the complex types of trailing cable in B.S. 708 and B.S. 1,116 are included of sheer necessity. Moreover, it would be an advantage if the minimum number of alternatives were adopted for ship installations. The special-purpose specifications have undoubtedly come to stay, and their scope and number will increase with time. Hence, it is most important that they should be most carefully reviewed to ensure that they are confined to essentials.

Some review and co-ordination of the high-voltage tests specified at the works and after installation are necessary. In the first place, it should be axiomatic that the test voltages applied bear a definite relation to the designed working voltage irrespective of the type of dielectric. Secondly, it appears logical to apply a relatively high test pressure to the lower-voltage cables and to decrease the ratio of test voltage to designed working voltage as the latter is increased. These principles are generally adopted in the present standards, but there are some obvious divergencies between one type of insulation and another. For instance, while it has been common practice in the past to apply a test voltage of 3,500 between the cores of all types of 660-volt cables, the latest trend for rubber insulation is in favour of 3,000 volts, while in the recent specification for 660-volt jute-insulated cables the test voltage is only 1,500. Again, for 6,600- and 11,000-volt cables the test pressure at the works is higher for rubber insulation than for the corresponding paper and varnished-cambric dielectrics. Less variation exists in the tests after installation, but the values adopted for rubber, polyvinyl chloride and jute are lower than for paper and varnished cambric.

It is also clear from the testing clauses that some of the current specifications reflect the modern tendency towards the universal adoption of earthed, rather than unearthed, systems. Equal test pressures between cores and between cores and earth still persist in the whole of the rubber-cable standards, for paper, varnished-cambric and rubber cables for strip use, for 660-volt paper-insulated cables for mining work, and for 660-volt jute-insulated cable. For tests after installation, the principle of permitting an alternative direct-current test is general with very minor exceptions. The direct-current value is made 50 per cent. greater than the corresponding alternating-current test pressure, except for 660-volt jute cables, for both of which the test voltage is 1,000 volts. This low figure is most remarkable, particularly having regard to the low alternating-current tests which are applied both at the works and after installation. If it be decided to continue this somewhat outmoded design, these tests appear to warrant careful review. The relationship between applied test voltages and designed working pressures show many discrepancies and there appears no sound reason why this should be allowed to continue. Whatever values are finally selected, the principle of making the core-to-earth test voltage $\frac{1}{\sqrt{3}}$ times that between the cores should be retained and there would appear to be good reason why the direct-current test after laying should be 50 per cent. greater than the corresponding alternating-current test wherever its inclusion is justified.

INSTITUTION OF NAVAL ARCHITECTS SCHOLARSHIP.—An Institution Scholarship in naval architecture, of the annual value of 175*l.*, and tenable for three or four years, according to the length of the course at the university selected, will be offered for competition in 1948 by the Institution of Naval Architects. The closing date for entries is January 15 next. Further information is obtainable from the secretary of the Institution, 10, Upper Belgrave-street, London, S.W.1.

JUNIOR INSTITUTION OF ENGINEERS.—The Council of the Junior Institution of Engineers have made a number of awards in respect of papers read, and lectures delivered, during the 1946-47 session. These include the Institution Premier Award to Mr. F. E. Bancroft, for his paper, "Penicillin and the Freeze Drying Process"; the Institution Prize to Mr. G. W. Tookey, for his paper, "The Trend of Patent Law"; the Vickers Prize to Mr. R. J. Birkinshaw, for his paper, "Short-Circuit Testing Stations for the Proving of Circuit Breakers"; the Tookey Award to Mr. H. K. Hewett, for his paper, "Water-Pumping Machinery"; the Past-Secretary Dunn Award to Mr. H. F. J. Higgs, for his lecture, "Notes on Major Landing Craft"; the Midland Section Prize to Mr. N. R. Holbrook, for his paper, "High-Temperature Pyrometric Technique"; and the Sheffield Section Prize to Mr. C. B. Harley, for his paper, "Steam Locomotives for Express Traffic on the Railways of Great Britain." An additional award has been made to Mr. S. J. Moore, for his paper, "Fluid Motion in Curved Pipes."

THE ELDER DEMPSTER MOTOR LINER "ACCRA."

THE launching of this vessel on February 24, 1947, together with a brief account of her main features, was recorded in ENGINEERING, vol. 163, page 187 (1947), and our present description amplifies the particulars already given and includes some illustrations of the ship. The Accra is the first of two new passenger and cargo liners to be completed by Messrs. Vickers-Armstrongs Limited, Barrow-in-Furness, for Messrs. Elder Dempster Lines, Limited, Liverpool; her sister ship, the Apapa, was launched from Barrow shipyard on August 18, and the photograph reproduced in Fig. 1, on page 560, shows the Accra putting to sea for trials on September 19. The vessel was specially designed for the owner's service between Liverpool and the West African Colonies, and is a twin-screw motorship of 11,585 tons gross, with a raked stem and cruiser stern. She has an overall length of 471 ft., the length between perpendiculars being 445 ft., a moulded breadth of 66 ft., and a moulded depth of 36 ft. 6 in. to the upper deck, "D." With a cargo space of 278,000 cub. ft. (bale), her deadweight capacity is estimated at 6,857 tons on a draught of 25 ft. 6 in., and the designed service speed of the vessel is 16 knots. The ship has six cargo holds, No. 4 hold over the tunnel flat being divided into three insulated cargo chambers, and the long cargo holds, Nos. 1, 2, 5 and 6 being free from obstructions, except for one pillar at the port and starboard sides in each space. The insulated cargo spaces are arranged for the carriage of meat and vegetables on the outward passage, and bananas will be carried on the homeward voyage. There are four continuous steel decks—lower, main, upper and bridge, with a promenade deck and boat deck, designated "F," "E," "D," "C," "B" and "A," respectively, and eight transverse watertight bulkheads have been fitted. The Accra has been designed to carry 245 first-class and 24 third-class passengers, and arrangements have been provided for the carriage of 145 coastal deck passengers, travelling between West African ports. Electric welding was used extensively in the construction of the hull, and unit prefabrication was carried out on a considerable scale.

In view of the extremes in climatic conditions which exist between this country and West Africa, careful consideration was given to securing the maximum degree of comfort for passengers, and the whole of the accommodation is ventilated and heated on the Thermotank system. The accommodation for the first-class passengers is arranged on the upper and bridge decks, "D" and "C," in single- and double-berth cabins, and 14 of the latter are fitted with a Pullman berth for an additional passenger. On "D" deck, forward, 12 single-berth and eight double-berth cabins are provided with private bathrooms, while the remaining first-class cabins each have a shower cubicle. A private suite, comprising a sitting-room, bedroom, bathroom and boxroom, is situated on the bridge deck.

The third-class passenger accommodation is arranged aft on the main deck "E," and consists of six four-berth cabins with adjacent lavatory accommodation, and the separate dining saloon and covered promenade is immediately above on the upper deck, "D," on which, at the forward end, the coastal deck passengers are carried. The captain and deck officers are accommodated in a house on the boat deck forward, with direct access to the navigating bridge above, while the engineers' accommodation is built around the engine casing amidships on the same deck, the officers' mess and separate smoke room being on the starboard side. The public rooms for the first-class passengers comprise a large dining saloon, which extends for the full width of the ship on the main deck, with a lounge, library, smoke room and card room on the promenade deck; the rooms on this deck are situated between the forward and after entrance halls and connected by a wide corridor. The lounge is fitted with casement windows in the front and sides, and those facing forward follow the curve of the bridge front. There is a tiled swimming pool at the after end of the boat deck, and when this is decked over by portable covers, the area provides a games deck extending the full width of the ship, while immediately below, on the promenade deck, there is a large dancing space. The accommodation for the European crew is situated aft on the main deck, and that for the African crew is forward on the same deck.

The main propelling machinery of the Accra, arranged as shown in the plan of the engine room, Fig. 4, on page 564, consists of two sets of Vickers-Doxford four-cylinder opposed-piston oil engines, having cylinders of 670 mm. bore with a combined stroke of 2,320 mm., and capable of developing 9,400 aggregate brake horse-power on service when running at 118 r.p.m. Each engine is fitted with a single crank-driven double-acting scavenge pump between Nos. 2 and 3 cylinders, high-pressure fuel pumps, electrically-driven turning gear, and a Bibby-Doxford detuner for

ELDER DEMPSTER MOTOR LINER "ACCRA."

MESSRS. VICKERS-ARMSTRONGS LIMITED, LONDON.

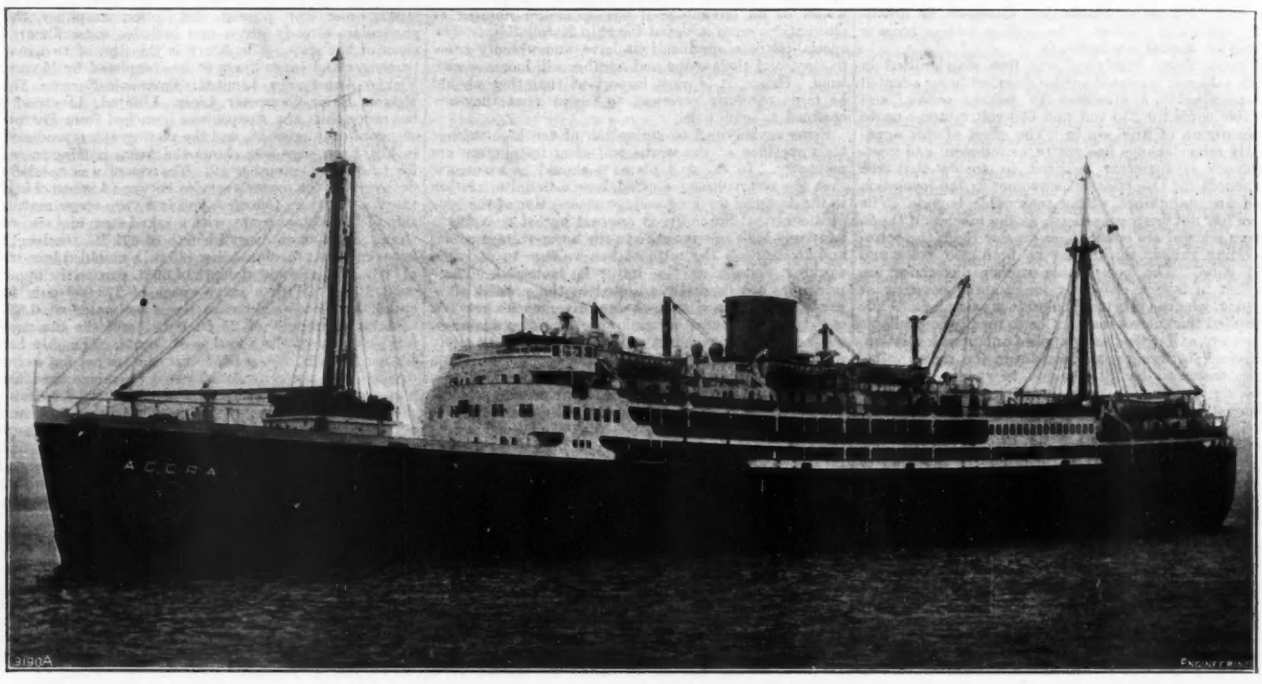


FIG. 1. VESSEL LEAVING BARROW FOR TRIALS.

reducing torsional-vibration stresses in the crankshaft. While the engines are of normal Doxford design some special features and modifications have been incorporated to improve reliability and performance, and these comprise the fitting of an additional strainer to the high-pressure fuel supply at each fuel-spray valve, strengthening of the joints of the cooling-water flanged connections in the crankcase, an interlock in the controls between the air-starting valve and the reversing lever, and the fitting of an air-operated brake to the intermediate shafting of each engine. A view of the engines, at the control platform, is given in Fig. 2, on page 564, while Fig. 3, on the same page, illustrates one of the brakes and control gear on test, the shafting being driven by an electric motor, in the works of Messrs. Vickers-Armstrongs Limited. The brakes, which are located on the first length of intermediate shafting aft of the engines, have been fitted to expedite the response to an urgent order from the bridge to go from full ahead to full astern; unless the main engines can be brought to rest quickly, time is lost in waiting for them to slow down before reversal can be effected. The brake drums are forged solid with the intermediate shafting, and by a modification to the travel of the piston of the engine air-starting control valve, the supply of low-pressure air to the brake is controlled by the air-starting lever in such a way that it is impossible to have starting air on the engine and air on the brake at the same time. For normal starting, the air-starting lever is pushed away from the operator, and when the brake is required a lock has to be released and the lever is then pulled towards the operator.

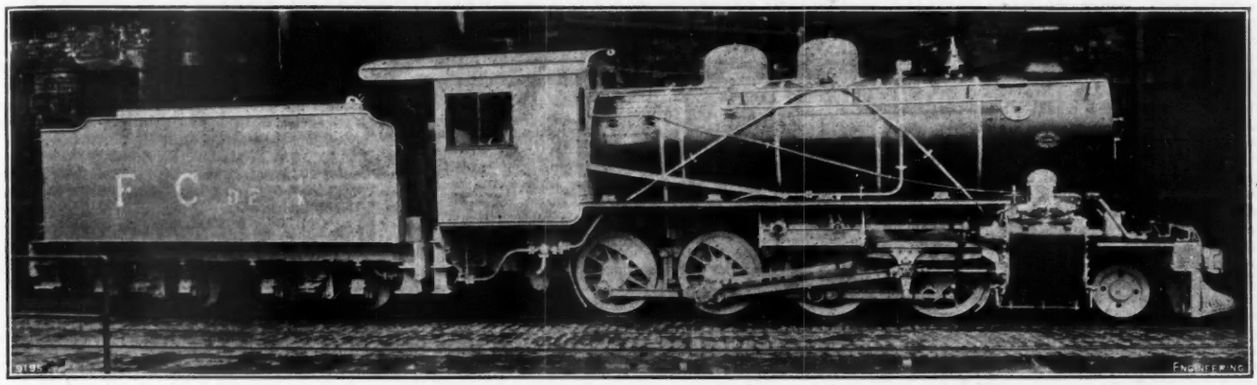
The compressed air for starting the main engines and the four Diesel-driven generators is provided by two air compressors, *a*, *a*, in Fig. 4, manufactured by Messrs. Peter Brotherhood, Limited, Peterborough, and driven by electric motors supplied by Messrs. W. H. Allen, Sons and Company, Limited, Bedford. Each compressor has a capacity of 200 cub. ft. per minute to a pressure of 600 lb. per square inch, and the starting air is stored in three air bottles on the lower deck above the compressors. The machinery spaces are ventilated by two motor-driven fans arranged on top of the casing abaft the funnel, and each fan has a capacity of 36,000 cub. ft. per minute against a total water gauge of 1·435 in. The fans were supplied by Messrs. Axia Fans, Limited, London, and the motors by Messrs. W. H. Allen, Sons and Company, Limited. A 6-ton single-motor overhead crane, manufactured by the Wharton Crane and Hoist Company, Limited, Reddish, Stockport, is provided for overhauling the main machinery. The four-bladed propellers, which have the blades cast solid with the boss, were supplied by the Manganese Bronze and Brass Company, Limited, London. The electrical power for the ship is supplied by four Diesel-driven 220-volt direct-current generators, manufactured by Messrs. W. H. Allen, Sons and Company, and arranged forward of the main engines as shown in Fig. 4. Each set has a six-cylinder engine and an output of 275 kW when running at 410 r.p.m., and is complete with engine-driven lubricating-oil and fresh-water pumps, lubricating-oil coolers, and Stream-Line oil filters, *b*, *b*, *b* and *b*. Monitor alarms are fitted to the lubricating-oil and fresh-water systems. An emergency dynamo, driven by an 81-brake horse-power Paxman-Ricardo five-cylinder Diesel engine, is housed in a room on the boat deck, next to and forward of the engine casing. The low-pressure circuits of the ship are supplied by duplicate 25-volt 15-ampere motor-generators, manufactured by Messrs. Metropolitan-Vickers Electrical Company, Limited, London, and situated on the main switchboard flat over the main generators. All the switchboards, including the main board at the forward end of the engine room and 13 auxiliary boards fitted throughout the vessel, were manufactured by Messrs. Whipp and Bourne, Limited, Castleton, Rochdale. The main switchboard is of the dead-front type and consists of a centre metering and control panel, for paralleling the dynamos, with two dynamo-control panels and nine branch breakers on the port side and two dynamo breakers and six branch circuit breakers on the starboard side. Of the 13 auxiliary switchboards, three in the engine room are of the dead-front type, the remainder being of the flat-back type, and these boards feed the engine-room auxiliaries, the winches, the refrigerating machinery, passenger and service lighting, and the ventilation, domestic and emergency circuits. In the event of a failure in the supply from the main generators, a 25-volt Nife battery comes into operation automatically to provide illumination in the engine room and machinery spaces.

The fuel oil is carried in the double-bottom compartments under the machinery space and Number 3 hold, and also in four deep tanks, two port and two starboard, at the forward end of the engine room. The fuel-oil overflow tank is in the double bottom under the generators, and large settling tanks are situated at the after end of the engine casing. A motor-driven oil-transfer pump *c*, having a capacity of 50 tons per hour and supplied by Messrs. Drysdale and Company, Limited, Yoker, Glasgow, with two Alfa-Laval centrifugal oil purifiers, *d*, *d*, each of 4 tons per hour capacity, and two oil heaters, *e*, *e*, are provided to deal with the fuel oil. The main engine-jacket and piston-cooling water pumps, *f*, *f*, *f*, of which two are working pumps and one a standby, are mounted on top of the distilled-water suction tank and each pump has a capacity of 200 tons per hour. Two Serck coolers, *g*, *g*, are installed for cooling the main-engine circulating water, and the sea water for these coolers and other duties is supplied by two circulating pumps, *h*, *h*, each having a capacity of 270 tons an hour. Both sets of pumps were manufactured by Messrs. Drysdale and Company, the sea-water circulating pumps being of their "Upright" type. Messrs. Drysdale also supplied the lubricating-oil pumps, *i*, *i*, *i*, each of which has a capacity of 45 tons per hour; the pumps are of the "Vertoil" type. The electric motors for all these water and oil pumps were supplied by Messrs. Campbell and Isherwood, Limited, Bootle, Liverpool, and the starters by Messrs. Igranic Electric Company, Limited, London. The lubricating-oil system of each main engine is separate and complete with Auto-Klean strainers, *j*, *j*, and Serck oil coolers, *k*, *k*, and the drain tank in the double bottom at the after end of the engine room has an oiltight division making two separate compartments. Two Alfa-Laval centrifugal oil purifiers, *l*, *l*, are installed for cleaning the lubricating oil. An auxiliary circulating pump, *m*, with a capacity of 65 tons per hour, is provided for circulating sea water through the coolers of the Diesel generators. This pump was manufactured by the Hamworthy Engineering Company, Limited, Poole, and is driven by a motor supplied by Messrs. Laurence Scott and Electromotors, Limited, Norwich. The circulating-water and lubricating-oil systems are protected by Aspinall's electric alarms.

The ship's service pumps include two fire and bilge pumps, *n*, *n*, each having a capacity of 110 tons to 70 tons an hour against a head of 50 ft. to 140 ft., a ballast pump, *o*, of 270 tons to 80 tons an hour capacity against 70 ft. to 140 ft. head, a sanitary pump, *p*, of 70 tons an hour capacity against 140 ft. head, and two domestic fresh-water pumps, *q*, *q*, each of 30 tons an hour capacity against a head of 115 ft. All these pumps were supplied by Messrs. Drysdale and Company, and are driven by Campbell and Isherwood motors with starters by the Igranic Electric Company. An emergency submersible fire and bilge pump, also manufactured by Messrs. Drysdale and Company, and having the same capacity as the fire and bilge pumps, *n*, *n*, is situated in the after sewage compartment on the inner bottom, and is driven by a motor supplied by Messrs. Laurence Scott and Electromotors, Limited. For the Sprinkler system, a "Medivane" pump, *r*, manufactured by Messrs. Mather and Platt, Limited, Manchester, is installed in the engine room, the air compressor and pressure tank being above it on the lower

OIL-BURNING LOCOMOTIVE FOR PERU.

THE HUNSLET ENGINE COMPANY, LIMITED, LEEDS.



deck, and a Comyn oily-water separator, *s*, supplied by Messrs. Alexander Esplen and Company, Limited, Liverpool, is provided. The fire extinguishing apparatus for the machinery spaces is of the Phomene type and comprises two 30-gallon units and seven two-gallon units, together with two extinguishers filled with C.T.C. for electrical fires. All baths and showers in the ship are supplied with fresh water; no hot salt water being used for this purpose, and the fresh water is obtained from a large evaporating and distilling plant, *t*, with a capacity of 60 tons per 24 hours, manufactured by Messrs. Buckley and Taylor, Limited, Oldham. The plant is of the low pressure Quiggin type, working under compound effect when supplied with 4,000 lb. of steam per hour at 120 lb. per square inch pressure, and is complete with a pump, *u*, also supplied by Messrs. Buckley and Taylor, Limited, a distiller condenser, *v*, and an evaporator cooler, *w*, fixed below the condenser. Steam for the evaporating plant, Thermotank heating, and other purposes, is supplied by two Clarkson thimble-tube composite-type boilers, situated as shown in Fig. 4 and mounted on the level of the lower deck. The boilers are fitted with low-pressure oil burners and each boiler can produce 3,900 lb. of steam per hour at 120 lb. per square inch from exhaust-gas heating and 4,500 lb. of steam per hour from oil firing, to give a total output from each boiler of 8,400 lb. of steam per hour at a pressure of 120 lb. per square inch. The oil-burning plant was supplied by Messrs. Clyde Fuel Systems, Limited, Hillington, Glasgow, and is complete with electrical heaters and automatic fuel cut-off in the event of the flame being extinguished. The two boiler-feed pumps, *x*, *x*, were supplied by Messrs. G. and J. Weir, Limited, Cathcart, Glasgow, and the feed heater, *y*, is heated by the exhaust steam from these pumps. The boiler fuel oil tank, of 3 tons capacity, and a calorifier, with a hot-water storage tank above, are situated in the engine room casing at bridge deck level.

The refrigerating machinery is situated aft of the engine room and immediately below the insulated cargo chambers in No. 4 hold. The equipment consists of two CO_2 compressor sets, each driven by a 52-h.p. electric motor, a sea-water circulating pump driven by a 3½-h.p. motor, and three brine pumps with motors of 3 h.p. each. The compressors, CO_2 evaporators and condensers were supplied by Messrs. J. and E. Hall, Limited, Dartford, the compressor motors being manufactured by Messrs. Campbell and Isherwood, Limited. Arrangements have been made for possible future additions to the refrigerating plant, if required, and the switchgear and distribution boxes provide for an increase in power, up to 60 h.p., for extensions. The heating and ventilation plant for the whole of the accommodation was supplied by Messrs. Thermotank, Limited, Govan, Glasgow, and consists of 19 steam-heated Thermotank units with four supply and 26 exhaust fans. The system includes a fresh-water filtration plant consisting of two vertical-type Uneek filters, capable of dealing with 20 tons per hour, together with a chemical treating plant and sterilising apparatus. The deck machinery comprises a 59-h.p. windlass on the bridge deck forward, a 38-h.p. warping winch on the same deck aft, and 14 motor-driven cargo winches of 38 h.p. to serve the six holds. The windlass was supplied by Messrs. Stothert and Pitt, Limited, Bath; the warping winch by Messrs. Clarke, Chapman and Company, Limited, Gateshead, and both units are controlled by contactor-type gear, the master controller being adjacent to the unit with the contactor controller and resistance units mounted below decks. The cargo winches, also supplied by Messrs. Clarke, Chapman and Company, are capable of lifting 4 tons at a speed of 110 ft. per minute, or 2 tons at 220 ft. per minute, and their control gear is of the contactor type, mounted on the winch bed. The vessel is fitted with an electro-hydraulic steering gear of four-cylinder design supplied by Messrs. John Hastie and Company, Limited, Greenock, and operated by a Hele-Shaw pump driven by a 40-h.p. electric motor. A second pump and motor set is provided as a standby. The starters, supplied by Messrs. Igranic Electric Company, Limited, have duplicate automatic operating coils, to ensure that should one set fail the other will function and start the motor.

Lifeboat accommodation is provided by eight boats carried under Welin MacLachlan gravity-type davits. They comprise two 26-ft. wooden "accident" lifeboats, one at each side of the officers' house on the boat deck, four 31-ft. Birmabright lifeboats fitted with Fleming hand-propelling gear, two each side of the funnel casing on the boat deck, and two 28-ft. steel lifeboats, one of which is engine-driven, arranged one on each side of the promenade deck aft. The vessel meets the latest recommendations for precautions against fire, and closely-spaced fire screen bulkheads, with screens around the main stairways, are fitted. Each cargo hold and 'tween decks is provided with smoke-detecting and CO_2 fire-extinguishing pipes, and all passenger and crew spaces are protected by a Grinnell automatic sprinkler system. The main galley, the crew's and the native galley, are equipped with electrically- and steam-heated appliances supplied by Messrs. Henry Wilson and Company, Limited, Liverpool, who also supplied the main-deck and officers' pantry equipment. The total galley and domestic electrical load is about 410 kW, of which the galleys take 220 kW. The laundry is situated on the bridge deck aft, and is completely fitted out with machinery supplied by Messrs. Thomas Bradford and Company, Limited, Salford. The navigational equipment of the Accra includes a Hughes type M.S.XII.C echo sounder, a Walker's log, a gyro-compass equipment manufactured by Messrs. S. G. Brown, Limited, London, a Metropolitan-Vickers type MN1 radar installation and a Lodestone direction finder, supplied and fitted by the Marconi International Marine Communication Company, Limited, Chelmsford. Communication for navigational purposes is provided by Pharos two-wire telephones, manufactured by Messrs. Alfred Graham and Company, Limited, Halifax. A four-way telephone in the wheelhouse gives communication with the forecastle, docking bridge, engine room and gyro-compass room, and direct lines are provided between the engine room and the chief engineer's cabin and between the docking bridge and steering gear compartment. The wireless telegraphy installation, which was also supplied by the Marconi International Marine Communication Company, consists of an Oceanspan main transmitter, capable of direct communication with the United Kingdom from all parts of the world, and a Yeoman main receiver. The vessel is also fitted with Marconi equipment for broadcasting announcements, wireless and gramophone programmes, etc.

FILM-STRIP PROJECTOR.—Messrs. Moviegram (Equipments), Limited, 3, Albemarle-street, Piccadilly, London, W.1, have sent us details of a cabinet for showing sound films in daylight, for educational and publicity purposes.

OIL-BURNING LOCOMOTIVE FOR PERU.

THE Hunslet Engine Company, Limited, Leeds, 10, have recently built a 2-8-0 oil-burning locomotive for the Trujillo section of the Peruvian Corporation Railways. The makers believe that it is the most powerful non-articulated steam locomotive built for a 3-ft. gauge railway; a photograph of it is reproduced on this page. The tractive effort at 75 per cent. boiler pressure is 25,200 lb., and the engine has been designed to the requirements of Mr. T. Jefferson, locomotive superintendent of the Peruvian Railways, to haul 400-ton freight trains up gradients of 1 in 50, and round curves of 100 m. radius. The Corporation's consulting engineers, Messrs. Livesey and Henderson, 14, Southplace, London, E.C.2, were responsible for the specification and inspection of the locomotive.

The total weight of the engine is 53 tons 10 cwt.; the adhesive weight is 47 tons 18 cwt., distributed equally over the four coupled axles, and the factor of adhesion is 4·25 to 1. The frames are cut from steel slabs 4 in. thick, and connected by cast-steel and steel-plate stretchers and drag boxes. The boiler has a round-topped shallow firebox, suitable for oil burning, and is fitted with Longstrand-steel side stays, and Flannery flexible bolts in the breaking zones. The internal diameter of the barrel is 5 ft. 0⅞ in., and there are 129 Aquacidox steel tubes of 2-in. outside diameter, and 21 superheater-flue tubes of the same material, 5½ in. in diameter and 12 ft. 4 in. in length. The areas of the heating surfaces are 1,184 sq. ft. for the tubes and flues, 110 sq. ft. for the firebox, and 200 sq. ft. for the superheater elements. The boiler pressure is 180 lb. per square inch, and the "grate" area is 23 sq. ft. The lower half of the firebox, and a pan below the box, are lined with firebricks. The oil-burner is supported on a quick-release mounting at the front of the firebox, to facilitate cleaning. The boiler is fitted with two 2½-in. Ross safety-valves; a Superheater Company's multiple-valve regulator in the header; and two Gresham and Craven injectors, delivering through top-feed valves.

There are two outside cylinders, 18½ in. in diameter by 24-in. stroke, each cast integral with one half of the smokebox saddle. Walschaerts gear actuates 9-in. piston-valves, giving a maximum travel of 4⅜ in. at 80 per cent. cut-off. The steam lap is 1 in., and the lead is ¼ in. The piston rods are fitted with Britimp metallic packing, and are cottered to Laird-type double-bar crossheads. The connecting rods, 8 ft. 2 in. between centres, drive the third pair of coupled wheels, which are 3 ft. 8 in. in diameter. The rigid wheelbase is 13 ft. 6 in., the coupled wheels being disposed equally over this distance, and the total engine wheelbase is 20 ft. 3 in. Cast-steel axleboxes with bronze bearings and whitemetal inserts are fitted in the horns, which have adjusting wedges at the rear. The springs throughout the engine are equalised. A steam brake is applied to all coupled wheels and tender wheels.

The tender is supported by two four-wheeled diamond-frame bogies with transverse laminated springs. The diameter of the wheels is 2 ft. 2 in., the distance between the wheel centres is 4 ft. 6 in., and the distance between the bogie pivots is 8 ft. 9 in. The tare weight of the tender is 17 tons and the laden weight 35 tons 5 cwt.; the tender has a capacity of 1,200 gallons of oil and 3,000 gallons of water. The overall length of the locomotive and tender is 53 ft. 5¾ in., the height to the top of the chimney is 12 ft., and the maximum width over is 8 ft. 10¼ in.

TESTING AND SERVICING ELECTRONIC EQUIPMENT.

AT a meeting of the Radio Section of the Institution of Electrical Engineers on Tuesday, November 11, a discussion on "What Equipment is Necessary for Servicing and Testing Electronic Devices?" was opened by Group Captain P. Allerston. He said that in the case of a fixed-wave broadcasting station, where space was of no account, practically all the necessary testing aids could be included in the installation to give "self-checking" facilities at key points in the circuits. Except for a portable multi-purpose meter, and, possibly, a frequency monitor, any other test equipment would be an extravagance. The position in regard to mobile stations was very different. Such an installation might consist of several equipments, telecommunications and radar, for instance, operating on widely different wavelengths and involving the application of various techniques. It was usually constructed in small easily-transportable units, which could be handled by one man in a confined space. These units were often inaccessible, and the assembly had to be as compact as possible, compatible with a reasonable degree of efficiency. The margin of safety was often reduced in order to satisfy the demands for small size and lightness. The need for simplicity in operation frequently increased the complexity. Airborne equipment was required to operate satisfactorily for long periods without expert attention and under extreme conditions of temperature, humidity and atmospheric pressure. Air-borne radio was subject to much rough and often unavoidable handling; and the radio fitter's experience was often restricted.

For example, one type of military aircraft carried seven different radio installations, ranging from radar equipment operating in the centimetre band to a radio compass operating on the lower frequencies. There were over 386 valves, varying from a simple diode to cathode-ray tubes, klystrons and magnetrons. To carry out a comprehensive check of the equipment required the use of 85 pieces of test gear, including signal generators, test oscillators, wavemeters, monitors, oscilloscopes, general-purpose meters of various types, high-grade resistance attenuators, pulse generators, field-strength meters and valve-test sets. Such a comprehensive check would take two men ten hours to complete and was obviously uneconomical to carry out except at infrequent intervals. The most satisfactory procedure was, therefore, to restrict the work in the aircraft to simple functional tests of performance, and to replace the equipment at scheduled periods by items which had passed a bench-performance test satisfactorily.

In the functional test, the only measurements which were essential were those of input and output, except in cases where measurement of the radiated frequency was necessary. Only two items of test equipment were really required for such a test: a small multi-purpose test meter and an instrument for measuring output. In the workshop, the equipment required was more comprehensive and the range of measuring devices should be restricted only by economic factors and by the ability of the personnel to use the instruments. From the economic point of view, it was a matter for closer study whether the equipment went to the test bench or whether the local mechanic was to be provided with elaborate test gear.

In the course of the discussion, several speakers put in a plea for design for easier servicing. During the war there had been no time for this, but there was now no reason why designers should not be more "test conscious." For example, it would help if, instead of having to penetrate the wiring of compact and complicated pieces of apparatus with test prods and crocodile clips, the test points most frequently required were brought out to the exterior of the unit. There was room for improvement in soldering technique in confined spaces, and in this connection mention was made of the use of a low-voltage arc in conjunction with an aluminium bit, which remained cool and did not damage adjacent components. To overcome the disadvantage of using the work as an electrode, a thin carbon pencil split longitudinally and separated by a strip of mica could be used. When applied to the soldering tag, the heating current was limited to a short length of the tag itself.

Opinions were divided on the best method of carrying out major overhauls. In general, it was thought that the apparatus should be sent to a fixed depot equipped with modern instruments and backed by an electrical standards organisation. With this arrangement, valuable test equipment could be maintained in good condition and the time of skilled personnel would not be wasted in travelling. On the other hand, the risk in some cases of damage and alteration of calibration in transit was the overriding factor. The scheme of the R.E.M.E. of annual visits with mobile gear to units for complete tests of equipment at a lower level than that for original acceptance, but higher than routine day-to-day checks, had much to recommend it.

BRITISH STANDARD SPECIFICATION.

THE following specification has been issued by the British Standards Institution. Copies are obtainable from the Publications Department of the Institution, 28, Victoria-street, London, S.W.1, at the price quoted at the end of the paragraph.

Safety Belts and Harness.—Following a number of fatal accidents through faulty belts, the Institution was asked to produce a specification for safety harness, and B.S. No. 1397 has now been issued to meet this need and to prescribe types of belts which will ensure safety in use. No attempt has been made, in the new specification, to design belts for any particular use, as it was felt that this would tend to restrict the ingenuity of the manufacturer and to retard the production of improved designs. Instead, the specification ensures that the materials and methods of manufacture employed will produce a belt of ample strength and it also specifies a method of test which ensures that the belt is designed in such a manner as to cause the least possible risk of injury to the wearer in the event of a fall. The method of testing, which is simple and practical, employs a jointed dummy resembling as far as possible a human body and having as nearly as possible the same weight distribution. The total weight of the dummy is that of a heavy man. It is dropped in the belt through the maximum height of fall which the anchorage allows and a careful study is made of the manner in which the fall is arrested. An examination of the belt itself, after the drop, is also made to discover whether any weaknesses in material or construction have become evident. [Price 2*s.* 6*d.*, postage included.]

BOOKS RECEIVED.

Art and the Industrial Revolution. By FRANCIS D. KLINGENDER. Published for Transatlantic Arts Company, Limited, by Noel Carrington, Royle Publications, Limited, 29, Percy-street, London, W.1. [Price 21*s.* net.]

Electrical Materials. A Survey of the Composition, Properties, Testing and Applications of the Conducting, Insulating and Magnetic Materials Used in the Electrical Industry. General Editor: E. MOLLOY. George Newnes Limited, Tower House, Southampton-street, Strand, London, W.C.2. [Price 5*s.* net.]

Ministry of Fuel and Power, and British Intelligence Objectives Sub-Committee. Technical Report on the Ruhr Coalfield. By a Mission from the Mechanisation Advisory Committee of the Ministry of Fuel and Power. Volume III. Appendix No. 25. *Germania Mine—Central Shaft.* H.M. Stationery Office, Kingsway, London, W.C.2. [Price 1*s.* net.]

Administration Report of the Aden Port Trust for 1945-46. The Secretary, Port Trust Office, Aden.

State of Illinois. State Water Survey Division. Bulletin No. 37. *The Causes and Effects of Sedimentation in Lake Decatur.* By CARL B. BROWN, J. B. STALL and E. E. DETURK. State Water Survey Division, Urbana, Illinois, U.S.A.

Engineering Tools and Processes. A Study of Production Technique. By PROFESSOR HERMAN C. HESSE. Sixth printing. D. van Nostrand Company, Incorporated, 250, Fourth-avenue, New York 3, U.S.A. [Price 5·60 dols.] Macmillan and Company, Limited, St. Martin's-street, London, W.C.2. [Price 28*s.* net.]

United States Bureau of Mines. Miners' Circular No. 60. *Miscellaneous Accidents in Bituminous-Coal Mines. Coal-Mine Accident-Prevention Course.* Section 7. Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., U.S.A. [Price 25 cents.]

University of Minnesota. Engineering Experiment Station. Bulletin No. 26. *Moisture and Temperature Control in Buildings Utilising Structural Insulating Board.* By PROFESSOR FRANK B. ROWLEY, PROFESSOR MILLARD H. LA JOY and EINAR T. ERICKSON. The Director, Engineering Experiment Station, University of Minnesota, Minneapolis 14, Minnesota, U.S.A. [Price 50 cents.]

Holland's Reconstruction in Facts and Figures. In English. The Information Service, Ministry of Reconstruction and Housing, The Hague, Holland.

Payment by Results in Building and Civil Engineering During the War. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 6*d.* net.]

The Ohio State University. Engineering Experiment Station. Bulletin No. 128. *Numerical Solution of Axisymmetrical Problems, with Applications to Electrostatics and Torsion.* By PROFESSOR GEORGE H. SHORTLEY and others. The Director, Engineering Experiment Station, The Ohio State University, Columbus 10, Ohio, U.S.A. [Price 30 cents.]

Ministry of Town and Country Planning. Town and Country Planning Act, 1947. *Explanatory Memorandum.* H.M. Stationery Office, Kingsway London, W.C.2. [Price 6*d.* net.]

PERSONAL.

The Minister of Fuel and Power has selected SIR NORMAN DUKE, K.B.E., C.B., D.S.O., M.C., at present Secretary of the Scottish Home Department, to be chairman of the Electricity Board for the South-East Area of Scotland, and MR. W. S. SAWTELL, M.I.E.E., to be deputy-chairman. These appointments will take effect on the constitution of the board under the Electricity Act, 1947, which is expected at an early date. Mr. Sawtell is the manager of the Fife Electric Power Company.

Consequent upon the appointment of MR. G. DODSON-WELLS, as Acting Chief Public Relations and Publicity Officer, London Passenger Transport Board, 55, Broadway, London, S.W.1, MR. W. R. ROBERTSON, who has been senior assistant to the Public Relations Officer since 1944, has been appointed Acting Public Relations Officer to the Board.

PROFESSOR PIERRE A. J. CHEVENARD, PROFESSOR SIR GEOFFREY TAYLOR, M.A., D.Sc., F.R.S., and DR. J. F. THOMPSON, executive vice-president and director, the International Nickel Company, Incorporated, have been elected honorary members of the Institute of Metals.

MR. L. H DOWNS, C.B.E., M.A. (Cantab.), M.I.Mech.E., has been elected a director of Messrs. Power-Gas Corporation, Limited, Stockton-on-Tees, and of Messrs. Ashmore, Benson, Pease and Company, Limited, Stockton-on-Tees. Mr. Downs will continue in his present position as managing director of Messrs. Rose, Downs and Thompson, Limited, Old Foundry, Hull.

MR. A. S. BISHOP, a director of the Goodyear Tyre and Rubber Company (Great Britain), Limited, Bushbury, Wolverhampton, has been elected chairman of the Tyre Trade Joint Committee, 9, Whitehall, London, S.W.1, in succession to the late SIR HAROLD KENWARD.

MR. O. A. PALLETT, supervisor of purchases to the British Thomson-Houston Company, Limited, Rugby, since July, 1945, has been appointed chairman of the purchasing committee of Messrs. Associated Electrical Industries, Limited, Crown House, Aldwych, London, W.C.2, in succession to MR. J. BILLINGTON, who will retire from that position on December 31.

MR. R. HALSALL, deputy secretary to the Central Electricity Board, and MR. S. M. RIX, secretary and assistant manager to the Lancashire Electric Power Company, have been appointed deputy secretaries to the British Electricity Authority, Portland-court, Great Portland-street, London, W.1.

Consequent upon the appointment of MR. R. F. HANKS, as vice-chairman of the Nuffield Organisation, as announced on page 538, *ante*, MR. C. E. ALDRIDGE has been appointed general manager of Messrs. Nuffield Exports, Limited. Mr. Aldridge will be succeeded as general sales manager by MR. D. HARRISON, sales promotion manager.

MR. A. T. GREEN, O.B.E., F.R.I.C., F.Inst.P., Director of Research of the British Refractories Research Association, has been appointed honorary general secretary of the British Ceramic Society, in succession to the late DR. J. W. MELLOR.

DR. R. JACKSON has now left the research department of Messrs. Hadfields Limited, Sheffield, and has taken up a post on the staff of the British Coal Utilisation Research Association, Leatherhead, Surrey.

MR. P. W. HYDE has joined the staff of the research laboratories of the General Electric Company, Limited, Wembley, Middlesex.

MR. GERALD F. P. FOX, A.M.I.Mech.E., has received the appointment of standards manager to the Society of Motor Manufacturers and Traders, Limited, 148, Piccadilly, London, W.1.

MR. ERNEST A. TURRALL, of Messrs. Dunlop Rim and Wheel Company, Limited, Foleshill, Coventry, has been appointed works manager of its No. 1 Factory.

MR. ERNEST CROSSE, M.I.Mech.E., has been appointed general manager to Messrs. J. Brockhouse and Company, Limited, Victoria Works, West Bromwich, Staffordshire.

MR. GEORGE COOKE, M.I.Mech.E., has been appointed chief engineer of the boiler department of Messrs. Simon-Carves, Limited, Cheadle Heath, Stockport, Cheshire.

L.M.S. DIESEL-ELECTRIC LOCOMOTIVE.—The London Midland and Scottish Railway Company announce that the first Diesel-electric locomotive to be built for experimental main-line service in Great Britain has recently been completed in the new Diesel shop of the Company's works at Derby. It will be recalled that the locomotive incorporates a 16-cylinder 1,600-h.p. Diesel engine and electric transmission, both designed and constructed by the English Electric Company, Limited, Stafford. The locomotive, L.M.S. No. 10,000, is designed to work either independently, or coupled to a second similar locomotive now under construction. Tests of the locomotive have been commenced, and more extensive trials, for comparison with steam locomotives, will be conducted later.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel.—Steel outputs are being maintained at an excellent level. Shipyards are participating in the slightly improved distribution, and re-rollers are also benefiting from increased tonnages of billets and slabs. The supply of sheet bars, however, is still below the sheet-makers' needs. Important tonnages of light sections and bars are included in re-rollers' deliveries for export against Period 4 allocations. Some good outputs of medium and heavy plates from the sheet mills are reported, but more light sheets are needed. The maximum use is being made of the raw material provided at the light mills, but only 80 per cent. of the rolling capacity can be utilised owing to the shortage in sheet-bars. Tubemakers continue to operate at full pressure, and considerable quantities of tube strips, round bars, and ingots are being consumed. The shortage of scrap, aggravated by severe weather conditions militating against sorting in the yards, continues to give rise to serious anxiety, especially as inroads have been made already into scrap and pig-iron reserves to maintain the high level of production at the steelworks. There is still no news of additional coke supplies for the unlit blast-furnaces which, in the case of the Clyde Iron Works alone, could provide 7,000 tons of pig-iron weekly for steel-furnace charges.

Scottish Coal.—The recent spasmodic outbreak of strikes in Lanarkshire and Ayrshire has been overcome, and production is again running at a rate equivalent to about 490,000 tons a week. Available tonnages of saleable coal are in excess of commitments, and deliveries to the principal consumers are generally higher than the allocation figures; authorisation to export surpluses is expected soon. The steelworks programme has been revised in a few details, but current deliveries are heavy, and some congestion is occurring through lack of stocking accommodation at one or two works. Industrial and steam fuels are adequate to meet users' requirements, and despite rising consumption, stocks are seldom encroached upon. Metallurgical coke is scarce. A steady demand for bunkers is being promptly met, but export cargoes have been limited to an occasional shipment of inferior grades of fuel.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Welsh Coal Trade.—Mining methods new to this country are to be introduced when a long derelict colliery at Nantgarw, near Cardiff, is opened up. The Government White Paper on Wales, which announced this, states that the two pits at the colliery will be operated electrically. A scheme for development at the colliery was in hand by the Powell Duffryn Company, who bought it some years ago, and it has been taken over by the Coal Board. As lower seams of coal will be worked, it will mean virtually the sinking of two new pits. The expected output is about 4,000 tons a day of gas and coking coals. A modern coke-oven plant, which will be installed at the colliery, will produce between 6,000 tons and 10,000 tons of coke a week, while the gas, estimated at about 10 million cub. ft. a day, will be made available for distribution in East Glamorgan and Monmouthshire. It was reported during the past week that the price of bunker coals shipped to the foreign bunkering depots will be on the basis of between 77*s.* 6*d.* and 80*s.* per ton f.o.b., according to quality. After freight and other charges have been met, this will bring the coal on a par with American and South African coals. Business has been difficult to arrange on the Welsh steam-coal market throughout the past week. The demand has continued active but supplies have been scarce, particularly for early delivery. Home consumers have been making heavy demands, but orders from the high-priority users are sufficient to absorb the bulk of the potential outputs for some months to come. As a result, there has been little to spare for shipment to ordinary customers abroad and the only deliveries made were limited quantities for special users in Eire and Canada. The demand for cokes and patent fuel was heavy but business was not easy to arrange.

Swansea Steel-Sheet Industry.—The market report issued by the Incorporated Swansea Exchange states that, last week, business in tin-plate was quiet, the volume of orders placed being smaller than it has been for some time. Makers, however, have well-filled order books and have little room for more orders for the current quarter. Home consumers have commenced to place orders for their requirements for the first quarter of 1948, and doubtless the market will become active. Quiet conditions ruled in the export market last week, and the volume of business transacted was disappointing. Steel sheets are in great demand and makers are unable to accept more orders for some months to come. Iron and steel scrap is needed, as some consumers are receiving only their bare requirements.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—Local brands of pig iron are fully taken up, and there is a considerable consumption of hematite irons. Finished iron is in active request, and some additional supplies of bar iron are being brought in from Derbyshire. A little more ferrous scrap for re-melting is being received at merchants' yards for sorting and dispatch to steelworks; much more scrap is needed. The production of steel is steadily increasing, but there are still considerable arrears of deliveries to rolling mills and forges which cannot keep pace with the requirements for sheets and bars. Agricultural-steel firms, none of whom has been conceded any priority for steel or fuel, are exerting further pressure for priority to permit them to work full time on the numerous orders on their books As it is, the works cannot be employed at full capacity. These firms have a great deal of work in hand in agricultural-machine parts and edge tools. Other tool factories are extremely busy, some having at least two years' work on their books. The production of railway materials has improved now that a little more steel is available, but much more steel is required, particularly axle steel. Wagon-repair shops are getting more material and have been able to accelerate repair work.

South Yorkshire Coal Trade.—It is likely that the ban on Saturday-morning work will be removed at some pits shortly, as a result of negotiations with the National Coal Board. Coal outputs show an almost general improvement; several pits have exceeded their target levels, and there is a probability that this tendency will continue. Industrial users have been able to satisfy current requirements and place a little to reserve. A disquieting feature is the handing in of notices on behalf of over 3,000 coke-workers to strike unless their demand for a shorter working week is conceded. Any stoppage would be serious, as coke is not abundant, and all coke-oven gas is urgently required by industry.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

General Situation.—North-East Coast iron and steel producing plants are operating at as high a level as conditions permit and are turning out record parcels of material, but the distribution of much-needed commodities still falls short of the demand and further expansion of the aggregate tonnage output depends on supplies of raw materials and semi-finished products. The position with regard to truck supplies has improved. The welcome speeding up in the handling of rolling stock has enabled a considerable clearance of tonnage accumulation awaiting delivery to be effected. Rather better supplies of commodities needed for essential home purposes are reported, and confidence is growing in a substantial increase in shipment to overseas customers. The output of Cleveland ironstone, and supplies of both foundry and steelworks scrap, are considerably lower than is desirable, and pig-iron is still wanted in larger quantities than are obtainable. The authorisations for steel distribution are understood to be greatly in excess of the material actually produced, and large cancellations of orders are unavoidable, either this month or as soon as the new system of selective priorities is introduced.

Foundry and Basic Iron.—Ordinary foundry pig-iron is not yet obtainable in parcels sufficient to meet users' requirements, but better supplies are expected in the near future. This year, consumers have managed to turn out their products in larger quantities than might have been expected, but to do so they have depleted their stocks of pig-iron and are now greatly in need of larger allocations which cannot be conceded until the idle blast-furnaces are re-kindled. The whole of the basic-iron make is passing promptly into use at the Tees-side steel furnaces, and larger deliveries would be welcome.

Hematite, Low-Phosphorus and Refined Iron.—East-Coast hematite firms are maintaining deliveries to regular customers, but users of low- and medium-phosphorus grades complain that the tonnage coming to hand is hardly sufficient for urgent needs. Manufacturers of refined iron are finding a ready sale for their products.

Manufactured Iron and Steel.—Makers of semi-finished iron have good bookings and finished-iron producers have extensive delivery obligations; the commitments of steel manufacturers are much greater than they can handle. The scarcity of steel semics is slightly less acute than of late, but users are still requiring larger deliveries than the producers can make and the report that arrangements for substantial imports from the United States is very welcome. The commodities in greatest demand are billets and sheet bars, but all descriptions of finished steel are in strong request. Manufacturers are making every effort to deal with the urgent needs of home customers, and exports are increasing.

NOTICES OF MEETINGS.

IT is requested that particulars for insertion in this column shall reach the Editor not later than Tuesday morning in the week preceding the date of the meeting.

JUNIOR INSTITUTION OF ENGINEERS.—*Sheffield Section:* Monday, December 15, 6.15 p.m., Royal Victoria Hotel, Sheffield. Symposium on "Liquid Fuels for Open-Hearth Furnaces."

INSTITUTION OF ELECTRICAL ENGINEERS.—*London Students' Section:* Monday, December 15, 7 p.m., Victoria-embankment, W.C.2. "Power Switchgear," by Mr. P. W. Castle. *North Midland Centre:* Tuesday, December 16, 6.30 p.m., Great Northern Hotel, Leeds. "The High-Pressure Mercury-Vapour Discharge," by Messrs. V. J. Francis and W. R. Stevens. *Scottish Centre:* Tuesday, December 16, 6.30 p.m., Royal Technical College, Glasgow. "Electrical Control of Dangerous Machinery and Processes," by Mr. W. F. Cooper.

INSTITUTION OF CIVIL ENGINEERS.—Tuesday, December 16, 5.30 p.m., Great George-street, S.W.1. "Mathematics in Relation to Engineering, with Special Reference to Shear Stress Determination," by Professor Sir Charles Inglis, F.R.S. *Yorkshire Association:* Friday, December 19, 7 p.m., Royal Victoria Station Hotel, Sheffield. "Riding Qualities of Roads," by Mr. W. J. O. Scott.

INSTITUTE OF REFRIGERATION.—Tuesday, December 16, 5.30 p.m., Institution of Mechanical Engineers, Storey's-gate, S.W.1. "Effect of Lubricants on Halogen Refrigerants," by Messrs. A. Shaw and A. Brandon.

CHEMICAL ENGINEERING GROUP.—Tuesday, December 16, 5.30 p.m., Geological Society, Burlington House, Piccadilly, W.1. "Glass Equipment in the Chemical Industries," by Mr. J. G. Window.

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS.—Tuesday, December 16, 6.15 p.m., 2, Savoy-hill, W.C.2. "British Patent Law and National Progress," by Dr. A. P. Thurston.

INSTITUTION OF THE RUBBER INDUSTRY.—*London Section:* Tuesday, December 16, 6.30 p.m., Caxton Hall, Victoria-street, S.W.1. "Terylene," by Dr. D. V. N. Hardy. *Southern Section:* Wednesday, December 17, 7.30 p.m., Polygon Hotel, Southampton. "Expanded Plastics," by Mr. S. B. Turner.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.—Tuesday, December 16, 6.30 p.m., 39, Elmbank-crescent, Glasgow. "Submarine Cables," by Capt. W. H. Leech.

INSTITUTION OF MECHANICAL ENGINEERS.—*Western Branch:* Tuesday, December 16, 7 p.m., Merchant Venturers' College, Bristol. "Engineers' Responsibility for Costs and Overheads," by Mr. F. C. Lawrence. *Midland Branch:* Thursday, December 18, 6 p.m., James Watt Institute, Birmingham. "The Rocket as a Weapon of War," by Sir Alwyn D. Crow. *East Midlands Branch:* Thursday, December 18, 7 p.m., School of Arts, Green-lane, Derby. "Petrol Injection Equipment," by Messrs. K. Brook and W. E. W. Nicholls. *Institution:* Friday, December 19, 5.30 p.m., Storey's-gate, S.W.1. James Clayton Lecture: "Problems Encountered by R.E.M.E. in the Field," by Maj.-Gen. Sir Bertram Rowcroft. AUTOMOBILE DIVISION. *Scottish Centre:* Monday, December 15, 7.30 p.m., 39, Elmbank-crescent, Glasgow. "Developments in Transmissions," by Professor E. M'Ewen. *Luton Centre:* Tuesday, December 16, 6.30 p.m., George Hotel, Luton. "Springs for Automoble Suspension," by Mr. B. Mackenzie. Also at *Western Centre:* Thursday, December 18, 6.45 p.m., Grand Hotel, Bristol.

CHEMICAL SOCIETY.—Wednesday, December 17, 5 p.m., Royal Institution, Albemarle-street, W.1. "Chemical Personalities a Century Ago," by Professor John Read, F.R.S. Thursday, December 18, 7.30 p.m., Chemical Society, Burlington House, Piccadilly, W.1. Discussion on "Infra-Red Spectra and Molecular Structure," opened by Dr. H. W. Thompson, F.R.S.

INSTITUTION OF LOCOMOTIVE ENGINEERS.—Wednesday, December 17, 5.30 p.m., Institution of Mechanical Engineers, Storey's-gate, S.W.1. Presidential Address on "The Challenge to Steam," by Mr. Julian S. Tritton.

DIESEL ENGINE USERS ASSOCIATION.—Thursday, December 18, 2.30 p.m., Caxton Hall, Victoria-street, S.W.1. Annual General Meeting. "Heavy-Oil Engine Working Costs, 1945-46."

INSTITUTION OF MINING AND METALLURGY.—Thursday, December 18, 5 p.m., Geological Society, Burlington House, Piccadilly, W.1. "Tin Mines of Pahang Consolidated Co.," by Mr. F. H. Fitch.

ROYAL AERONAUTICAL SOCIETY.—Thursday, December 18, 6 p.m., Institution of Civil Engineers, Great George-street, S.W.1. "The Work of the High-Speed Tunnel," by Prof. A. Thom and Mr. W. G. A. Perring.

INSTITUTION OF STRUCTURAL ENGINEERS.—Thursday, December 18, 6 p.m., 11, Upper Belgrave-street, S.W.1. "Relaxation Methods for Structures," by Professor R. V. Southwell.

ELDER DEMPSTER MOTOR LINER "ACCRA."

MESSRS. VICKERS-ARMSTRONGS LIMITED, LONDON.

(*For Description, see Page 559.*)

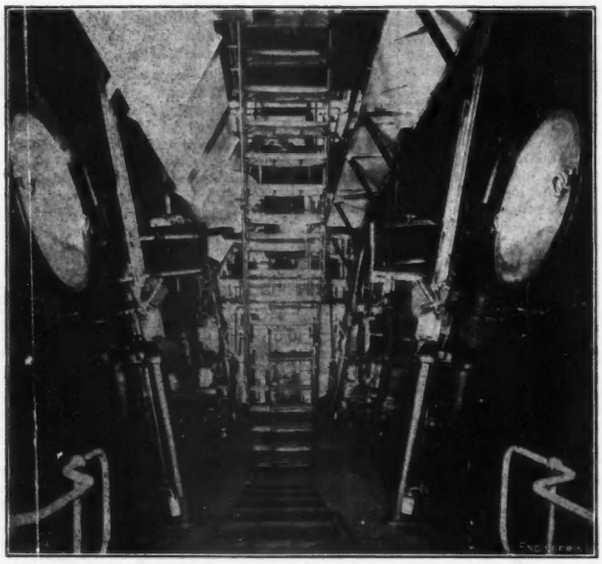


FIG. 2. ENGINE ROOM CONTROL PLATFORM.

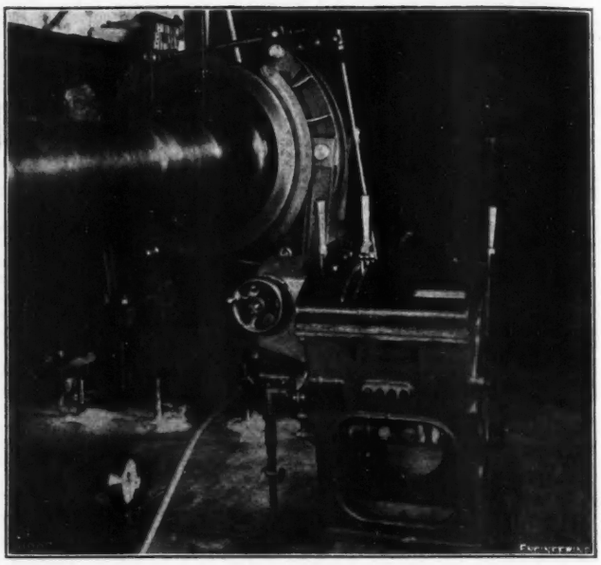
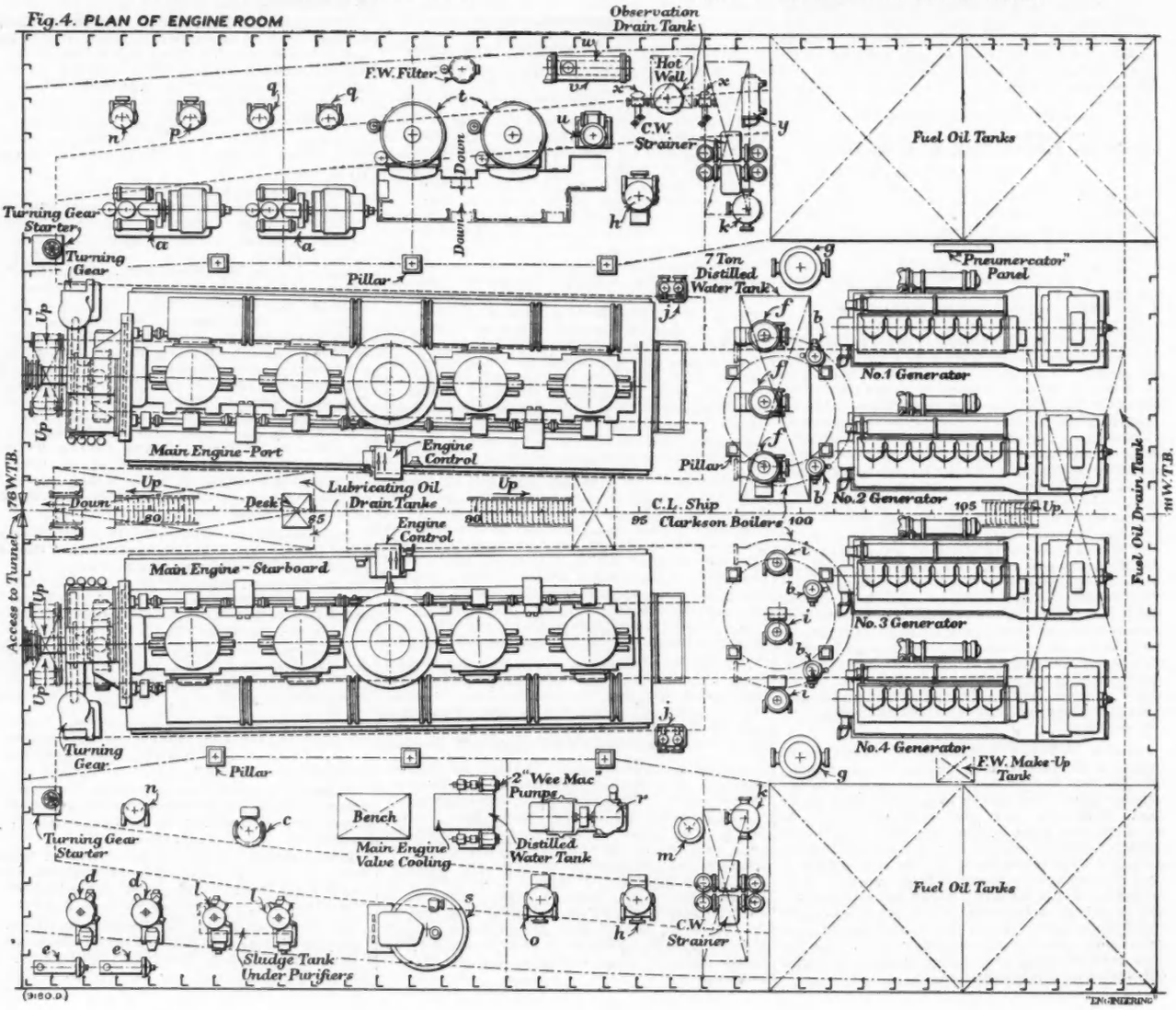


FIG 3. BRAKE GEAR ON TEST IN WORKS.

Fig.4. PLAN OF ENGINE ROOM



ENGINEERING.

35 & 36, BEDFORD STREET, STRAND, LONDON, W.C.2.

We desire to call the attention of our readers to the fact that the above is the address of our Registered Offices, and that no connection exists between this Journal and any other publication bearing a similar title.

Telegraphic Address:
"ENGINEERING," LESQUARE, LONDON.

Telephone Numbers:
TEMPLE BAR 3663 and 3664.

All editorial correspondence should be addressed to the Editor and all other correspondence to the Manager.

Accounts are payable to "ENGINEERING," Ltd. Cheques should be crossed "The National Provincial Bank, Limited, Charing Cross Branch." Post Office Orders should be made payable at Bedford Street, Strand, W.C.2.

SUBSCRIPTIONS.

"ENGINEERING" may be ordered from any newsagent in town or country and from railway bookstalls, or it can be supplied by the Publisher, post free, at the following rates, for twelve months (or for six or three months, *pro rata*), payable in advance:—

For the United Kingdom and all places abroad, with the exception of Canada	£4 10 0
For Canada	£4 5 0

Subscribers receiving incomplete copies through newsagents are requested to communicate the fact to the Publisher, mentioning the agent's name and address.

ADVERTISEMENT RATES.

Terms for displayed advertisements on the green art paper wrapper, on the inside black and white pages and in the buff art paper two-colour supplement, as well as for inserts, can be obtained on application to the Manager. The pages are 12 in. deep and 9 in. wide, divisible into four columns 2¼ in. wide. Serial advertisements will be inserted with all practicable regularity but absolute regularity cannot be guaranteed.

The charge for advertisements classified under the headings of "Appointments Open," "Situations Wanted," "Tenders," etc., is 8*s.* for the first four lines or under, and 2*s.* per line up to one inch. The line averages six words and when an advertisement measures an inch or more, the charge is 24*s.* per inch If use is made of a box number the extra charge is 1*s.* per insertion, with the exception of advertisements appearing under "Situations Wanted." Series discounts for all classified advertisements can be obtained at the following rates:—5 per cent. for six; 12½ per cent. for thirteen; 25 per cent. for twenty-six; and 33⅓ per cent. for fifty-two insertions.

TIME FOR RECEIPT OF ADVERTISEMENTS.

Classified advertisements intended for insertion in the current week's issue must be received not later than first post Wednesday.

"Copy" instructions and alterations to standing advertisements for display announcements must be received at least 10 days previous to the date of publication, otherwise it may be impossible to submit proofs for approval.

The Proprietors will not hold themselves responsible for advertisers' blocks left in their possession for more than two years.

CONTENTS.

	PAGE
The Story of Atomic Energy.—V (*Illus.*)	553
Literature.—Van Nostrand's Scientific Encyclopedia. Notes Introductory to the Theory and Design of Gas Turbines. The Principles of Technical Electricity	555
Brittle Fracture in Mild-Steel Plates.—I (*Illus.*)	556
Standardisation of Power Cables	558
The Elder Dempster Motor Liner "Accra" (*Illus.*)	559
Oil-Burning Locomotive for Peru (*Illus.*)	561
Testing and Servicing Electronic Equipment	562
British Standard Specification	562
Books Received	562
Personal	562
Notes from the North	563
Notes from the South-West	563
Notes from South Yorkshire	563
Notes from Cleveland and the Northern Counties	563
Notices of Meetings	563
Fuel and Power	565
Electricity Supply in 1943-44	566
Notes	567
Obituary.—Mr. R. P. Sloan, C.B.E.	568
Fifty Years Development of the Sulzer Diesel Engine	568
Portable Wood-Grooving Machine (*Illus.*)	570
The Engineering Centre, Glasgow	571
Labour Notes	571
Flow of Boiling Water through Nozzles, Orifices and Pipes (*Illus.*)	572
"ENGINEERING" Patent Record (*Illus.*)	576

ENGINEERING

FRIDAY, DECEMBER 12, 1947.

VOL. 164. No. 4272.

FUEL AND POWER.

ALTHOUGH economics and statistics are among the less superficially attractive features of technology, their importance is as little beyond dispute as the extent to which they can provide a firm basis for the consideration of large-scale industrial policy and organisation. It therefore becomes, in some sense, the duty of experienced engineers, with the welfare of their wide profession at heart, to inform themselves as fully as possible about the origins of the energy upon which engineering, in common with nearly all modern industry, depends. That duty is the more imperative inasmuch as engineering must play an increasingly significant part in realising and utilising latent resources of power for the benefit eventually of the nation as a whole. It implies, moreover, an obligation to plan for the future at least as wisely, and with as farsighted imagination, as is the avowed intention underlying the interconnected nationalisation of mines, electricity and gas generation, and transport. The value of the recent PEP (Political and Economic Planning) report on *The British Fuel and Power Industries** in furthering the fulfilment of that duty and its implicit obligations is inherently great, and is markedly enhanced by publication at a most opportune time.

PEP is an independent non-party organisation comprising a permanent research staff assisted by nearly 200 working members who, in their spare time, assemble and collate the subject matter for reports embodying suggestions for possible advances over a wide range of social and economic activities. They issued reports on the coal and the electricity supply industries in 1936, and on the gas industry in 1939. The present report revises the survey of those, and other minor, sources of power in the light of post-war conditions, and undertakes the formidable task of co-ordinating them with the principal power-consuming industries, in the belief that the decision of the present Government to nationalise certain major industries entails the risk that, in so doing, insufficient attention may be paid to technical and economic factors. The underlying aim of the statistical and other factual information collected in the report is, therefore, the constructive one of demonstrating how the highest efficiency is to be achieved in the major power industries when they are brought under national ownership, and how full co-ordination among them should be sought. It is necessary to distinguish, therefore, between the data, which are public knowledge, and their interpretation by PEP, which is realistic enough to accept nationalisation without vain argument about what might have been, but is liable to error of judgment as to what action may appear desirable. It is hardly within the scope of the report, moreover, to correlate the British fuel and power industries with developments in the international fields of industry and politics. Thus the field of PEP opinion on long-term fuel and power projects is inevitably limited; but these reservations detract little from the immediate merits of conclusions that are punctiliously non-partisan and scientifically detached.

The first, and not the least practically useful, achievement of the report is to set the various sources of British industrial power in true perspective, and thereby to demonstrate the supreme importance of coal. Over 90 per cent. of Britain's total fuel consumed is coal. Imported petroleum products account for 9 per cent., and well under 1 per cent. is provided by indigenous oil, hydro-electric power and other minor sources. Surveys of coalfields in 1945 put the proved reserves at approximately 40,000 million tons—equivalent to 200 years' supply at current rates of production. Such a predominance of a single source of latent energy has the important incidental effect of making coal the standard against which the economics of all other indigenous power resources must be measured. Individual schemes for acquiring power from oil, water, sewage gas, heat-pumps, atomic piles, windmills or the tides can be and remain feasible propositions only so far as they compete successfully with coal. It follows that an alternative to coal must fluctuate in value more or less with the real value of the equivalent coal, and it becomes a nice question how far such alternatives justify development concurrently with efforts to improve the production and utilisation of coal.

In the PEP view, these considerations point unmistakably to the conclusion that the future fuel and power requirements of the country can be met adequately only by increased coal production coupled with higher efficiency of utilisation. The possible development of atomic energy is not overlooked, but the prospects of energy on an industrial scale from plant of which the present output is measured in watts are so remote as to make no practical difference. Neither does the fact that coal output per man-shift began to fall before the outbreak of war, despite increased mechanisation, relieve the industry and its engineers from the demand for extended mechanisation, primarily in pits that are most urgently in need of improved haulage and loading methods. The PEP recommendations for exploratory work on new coalfields, and provision for training competent mine managers, are equally obvious contributions to the coal problem; but they do not touch the radical problem of achieving increased output with a mining labour force which, by all accounts, is diminishing in numbers and individual effectiveness. The temptation to employ stop-gap tactics, such as the concentration of effort on low-cost pits, is hardly to be resisted in existing circumstances, but such methods are not without risk of eventual waste if manual coal-winning becomes a lost art and no solution is sought or found for the mechanical exploitation of thin seams.

The attractive possibilities of underground gasification are important in this connection. The report refers to the experimental work started in Russia in 1935 and now being pursued in Belgium and in the United States, where a power station is being erected at a pithead to run on the products of underground gasification. The working group set up by the Ministry of Fuel and Power in 1944 to examine the potentialities of gasification undoubtedly has a very important remit, which should carry with it an equally constructive opportunity for the engineering profession to serve the nation; for the pithead power station, already aimed at on the grounds of ease and cheapness of coal supply, presents complex problems of distribution costs and cooling-water supply, which only experienced electrical engineers are wise enough to solve. The

* *The British Fuel and Power Industries.* Published by PEP, 16, Queen Anne's-gate, London, S.W.1. [Price 30*s.* net.]

incidental problem of utilising waste heat from generating stations for district heating adds a fresh complication, inasmuch as new and rebuilt towns are unlikely to be sited round collieries.

PEP has little criticism to offer as regards improvement of electricity and gas production. The compliment thereby implied to the engineers in those industries is doubtless gratifying, but all omission of reference to coal-burning gas turbines for large-scale generation is a little surprising, since the prospect along those lines of overall thermal efficiencies at least equal to those of modern steam-generating plant is almost certainly already within sight, while the raw-coal turbine looks to most engineers like being a practical proposition several years ahead of atomic energy for industrial service. Similar considerations apply to rail transport, in which connection PEP's conclusion that coal prices will, for the future, tend to favour electrification, seems to be at variance with present locomotive developments.

The report is also less than usually constructive in emphasising the scope for closer co-operation between the gas and coke-oven industries, admirable as it would undoubtedly be if the latter could guarantee both the quality and quantity of gas supplied to the former. It would have been more apposite to indicate how fluctuations, more especially of quantity, can be avoided within permissible limitations of new expenditure in the face of fluctuations in the requirements of coke-consuming industries that are totally unrelated to the largely seasonal variations in gas consumption. There is, however, much to be said in favour of efforts to reduce the sulphur content of town's gas. That would undoubtedly encourage the wider use of gas for "background" heating and reduce maintenance costs on equipment, with prospects of fuel economy on a big scale, since domestic fuel consumption, still predominantly of raw coal, offers a most fruitful field for improved efficiency. The idea of reducing the domestic consumption of raw coal and otherwise encouraging economical combustion by substantial price increases certainly has something to be said for it, but so much more is to be said against it as to put it almost outside practical consideration.

As regards some of the major fuel-consuming industries, the relation between fuel input and production output of goods is so direct, and increased production so essential, that greater efficiency in the widest sense of the term is a more urgent objective than restricted consumption. This seems to be the real sense of the PEP contention that the principal developments in the iron and steel industries, likely to lead to reduction in fuel consumption, are better geographical distribution of the industry, further integration (and, in some cases, elimination of uneconomic units), increased average size of blast furnaces, extended adoption of the basic Bessemer process, and, finally, increased utilisation of hot metal. In the textile industries, to take another example, PEP remarks on the outstanding extent to which power is provided through line shafting driven by steam engines, and suggests that substantial economies could be effected by electrification. Up to a point, and in many mills, especially in the cotton industry, this is, no doubt, true enough, but the PEP view is not beyond criticism for taking too little account of the value and convenience of low-temperature process steam in textile manufacture.

The fact that, here and there, the PEP report can be criticised in the light of present and prospective conditions affecting the political, financial and technical state of the country, serves rather to stimulate appreciation than detract from the high general merit of a document that is, indeed, full of food for thought. Not the least valuable and enduring feature of the work is the tabulation of data which will serve the fuel-producing and fuel-using industries with guidance in fashioning policy for years to come. For engineers, too, the statistical matter can be directly useful: but perhaps the most inspiring thing about this great report, for metallurgists and industrial technologists as well as engineers, is its incidental indications of the vast number of varied, but always worth-while, problems which only their efforts and skill will be able to solve.

ELECTRICITY SUPPLY IN 1943-44.

IN the computing year 1943-44, which ended on December 31 for companies, joint electricity authorities and the Central Electricity Board; on March 31 for local authorities and Joint Boards in England and Wales; and on May 15 for many Scottish local authorities, public authorities generated 20,883·1 million units of electricity and companies 16,723·3 million units, the respective percentages of the total generated being 55·26 and 44·25. The small difference of 0·49 per cent. required to make up 100 per cent. is represented by the units generated by the Central Electricity Board, which became a producer when the Earley Power Station went into commission. During this period, public authorities had 52,293 employees, or more than 58 per cent. of the total, and companies 34,842 employees, about 38 per cent. of the total, the difference from 100 per cent. again being made up by Central Board employees. Next year, all generation will be in the hands of public authorities, and if the same relative outputs per public and company employee are to continue to rule, a considerable increase in the total staff may be expected in due course. It is generally understood, however, that one of the main requirements of the country is more output per employee, not less. There is no reason to suppose that this comparison contains any hidden factor favouring company operation, as there were 52 public-authority stations of over 30,000-kW capacity, as compared with 29 company stations and the larger installations should show a greater output per employee. For small stations, up to 1,000 kW, each type of owner had 64.

The above figures have been extracted from the Electricity Commission return for the year 1943-44,* but the comparison that has been made naturally does not appear in the document, which is purely factual and is not concerned with relative performances or trends. In the main, the return must be looked upon as chiefly of historic interest, as the data which it presents are three years old. No doubt the labour involved in compiling a publication containing 260 pages of tabular matter partly explains the delay in preparing the return, and the collection of the necessary information may also have been difficult as the year covered fell within the war period. Present-day printing delays no doubt have also had much influence. Similar returns for the years 1944-45 and 1945-46 are in preparation and "will be published as soon as possible."

The figures refer to the last full year of the war and indicate tendencies which have since become more marked. The average cost per unit generated rose from 0·320 pence in 1942-43 to 0·329 pence. This increase is to be attributed entirely to rise in the cost of fuel, as salaries and wages fell from 0·027 pence per unit to 0·026 pence, and repairs, maintenance, oil, water and stores from 0·034 pence per unit to 0·032 pence. It is probable that this latter fall was due mainly to a decrease in the charge for repairs and maintenance, as activities under these heads had to be deferred owing to shortages of labour and materials and increasing load, which did not permit plant to be released for overhaul. The slight fall in salaries and wages was probably due to increased output with a reduction of about 1,000 in the total staff. The total units generated rose from 35,290 million in 1942-43 to 37,790 million, an increase of 7·1 per cent. The total capacity of plant installed increased from 11,679,042 kW to 11,972,391 kW.

The general development in supply during the year covered was influenced by the restrictions imposed on, or demanded from, domestic consumers. The total sales of electricity to all classes of consumers amounted to 31,904 million units, which represented an increase of 6·2 per cent. over 1942-43, the lighting, heating and cooking load, however, increased by only 3·8 per cent., while the power load rose by 7·8 per cent. The sales to consumers accounted for 84 per cent. of the gross supply, the remaining 16 per cent. representing works consumption and losses in transmission and distribution. It is stated in the return that at the end of 1943-44 the capacity of the generating plant installed was 20 per cent. in excess of the combined maximum demand on it, but in this connection it is to be remembered that the Electricity Commission is not concerned with the operation of power stations, and that those who are so concerned were probably only too well aware of the fact that a substantial proportion of this excess of 20 per cent. consisted of machines which would have been superseded in more favourable times. The load factor on the stations of authorised undertakers, taken collectively, was of the order of 43·3 per cent., compared with 42·2 per cent. in 1942-43.

At the end of the year under review, authorised undertakers, including the Central Electricity Board, owned or leased 364 generating stations, one less than in 1942-43. Of the 11,972,000 kW of generating plant which they contained, all except 220,000 kW or 1·8 per cent., was of the alternating-current type. The small percentages of direct-current plant was distributed over 144 stations, of which 68 contained combined alternating- and direct-current installations. The time was clearly not favourable for active implementation of a policy of eliminating direct-current stations, but the number decreased by three as compared with the previous year. Of the total of 364 generating stations, 114, or 31·3 per cent., each had an installed capacity of 25,000 kW or over, and they contained 89·8 per cent. of the total plant. There were 70 generating sets of 20,000 to 30,000 kW; 106 of 30,000 to 50,000 kW, and 41 over 50,000 kW. There were still six alternating-current stations operating on non-standard frequency, one belonging to a public authority and five to companies. All were of comparatively small capacity, the largest being a 145,000-kW station operating at 25 cycles and the smallest two 100-cycle stations, with a combined capacity of only 955 kW. Other frequencies in use were 40, 80 and 83 cycles.

The average cost of coal and coke, including handling, was 34*s.* 9*d.* a ton, as against 33*s.* 6*d.* in the previous year. The total consumption was 22,696,000 tons, including 3,854,000 tons of pulverised fuel. Of the total, 2,367 tons were used in producers serving gas-engine plants. This figure was 2,778 tons in 1942-43. Oil consumption for boiler firing showed a marked decrease as compared with 1942-1943, the relative figures being 3,253 tons and 6,192 tons. This effect was possibly mainly due to shipping difficulties affecting oil supplies, but rising prices may have had a bearing. A ton of oil fuel which in 1942-1943 cost 9*l.* 19*s.* 2*d.*, in 1943-1944 cost 11*l.* 6*s.* 7*d.* It is probable, however, that supply rather than price was the ruling factor in the case, as it has been in recent years, when oil has been substituted for coal without apparently any consideration of relative costs. The oil consumption for oil-engine plants did not show any great change, but even here there was a decrease to 11,339 tons from 12,012 tons. Water-power plants had an aggregate capacity of 346,389 kW, there being 118 machines. Of these, 39 were direct-current sets, which were evidently mainly of small size as their aggregate capacity only amounted to 84,667 kW.

The percentage of the units sold for lighting, heating and cooking was 30·73; for power, 65·64; for public lighting, 0·06; and for traction, 3·57; the corresponding percentages of revenue being 49·37, 47·73, 0·25 and 2·65. The actual revenue figure for lighting, heating and cooking was 66,470,163*l.*, and that for power 64,266,270*l.*, so that the domestic load brought in 2,203,893*l.* more than the power load, although it represented less than half the units. In connection particularly with the traction load, it is necessary to remember that this return is concerned only with authorised undertakers providing public supplies. To obtain a complete picture of the electricity-supply position in Great Britain in the year covered by the returns, it would be necessary to take account of the output of generating stations owned by railway and tramway authorities as well as of those owned and operated by collieries and other industrial undertakings.

* *Electricity Commission. Electricity-Supply, 1943-44. Return of Engineering and Financial Statistics relating to Authorised Undertakings in Great Britain for the Year 1943-44.* H.M. Stationery Office. [Price 1*l.* 1*s.* 0*d.* net].

NOTES.

BRITISH TRANSPORT COMMISSION.

SOME further decisions of the British Transport Commission have been made public since we briefly recorded the Press conference of Sir Cyril Hurcomb (the chairman), on page 519, *ante*. A "Scheme of Delegation of Functions by the British Transport Commission to the Railway Executive" has been approved by the Minister and published in accordance with Section 5 of the Transport Act, 1947. It is a legal document which establishes, *inter alia*, that the Commission is the legal owner of the undertakings, and the policy-making and financial body responsible for maintaining co-ordination between the several Executives; the Railway Executive is responsible for day-to-day operation and management of British Railways, is the body with which the public will deal, is the employer of railway staff, and will sue and be sued on all matters of dispute arising within the scope of the Scheme of Delegation. Nevertheless, the Commission retain the functions specified in Sections 76, 78, 79 and 80 of the Act, which are related to the preparation of charges schemes, and submission of these to the Transport Tribunal (the renamed Railway Rates Tribunal); and the Commission retain power to issue specific directions on such matters as they think fit, from time to time. Sir Cyril Hurcomb, and Lord Latham, chairman of the London Transport Executive, issued a joint statement on Friday, December 5, on the plans for London Transport, which will remain the short and well-known title. Apart from his duties as chairman, Lord Latham "will personally concern himself with general planning, research and development." Members of London Transport Executive will work as a team, but each full-time member will take full responsibility for the work of a number of departments, thus: Mr. John Cliff, staff and staff welfare; Mr. A. H. Grainger, civil and electrical engineering, supplies, and legal; Mr. L. C. Hawkins, finance, accounts and audit; and Mr. A. B. B. Valentine, operation and mechanical engineering. The part-time members are Sir Richard Burbidge, Sir Edward Hardy, and Mr. T. E. Williams. London Transport will take over responsibility for certain joint lines in and around London, and the Railway Executive will take over a few others. It has also been agreed that the London Transport Executive shall confine their operations to passenger traffic, and the limited amount of goods traffic now undertaken by the L.P.T.B. will be transferred as soon as possible to the Railway Executive. Sir Cyril Hurcomb's latest announcement concerns the absorption into the regions of the joint lines and minor railways of the country on January 1, 1948. The present duplicated supervision will be replaced by administration wholely within one region. This change may take some time to effect in certain instances, and the alteration of boundaries between regions at a later date may involve re-allocation of some of the present joint lines and minor railways.

THE IMPERIAL COLLEGE UNION VACATION WORK SCHEME.

The 13th annual report of the operation of the vacation work scheme for students of Imperial College, London, shows a continued increase in the number of students who avail themselves of the opportunities that it affords to obtain practical experience during the long vacation, and in the number of firms who co-operate to make this possible. The scheme applies to students at the Royal College of Science, the Royal School of Mines, and the City and Guilds College, and possesses the incidental advantage that it introduces to the notice of the firms some typical products of the respective colleges, from whom they may select future recruits to their technical staffs; many first appointments of college graduates are known to have originated in this way. The scheme is entirely voluntary, and its success is shown by the fact that the registrations in it for 1945, 1946 and 1947 were, respectively, 467, 586 and 705. During the past two years, there has been in operation also an international exchange system, whereby a certain number of Imperial College students are accommodated with firms abroad, and an approximately equal number, from the countries associated with the scheme, are given the opportunity to learn something of British engineering practice. In the summer of 1947, 222 students took advantage of this exchange, 106 from Imperial College going abroad and 116 students from the Continent visiting English firms. The countries participating, in the order of the numbers of students exchanged, were Sweden, Holland, Norway, Switzerland, Denmark, Belgium and France (equal, with 16 each), and Czechoslovakia and Finland (8 each). Two students went to Canada, and two made voyages to Persia in oil tankers. Seventy foreign firms and 55 British firms co-operated in the exchanges. The report mentions that only those British students who have previously engaged in vacation work at home are allowed to take such temporary posts abroad, unless they are ex-Service men; and that the Imperial College students who have been abroad have been so impressed by the cordiality of their reception that they have taken special steps to arrange to receive and entertain students from Continental countries.

GAS-TURBINE FUEL SYSTEMS.

At a meeting of the Institution of Mechanical Engineers, held on Friday, December 5, with Sir Claude Gibb, C.B.E., M.E., F.R.S., vice-president, in the chair, Dr. E. A. Watson, O.B.E., D.Sc., M.I.Mech.E., presented a paper for discussion, entitled "Fuel Systems for the Aero Gas Turbine." The author summarised the results of six years of work, with which he was associated, and dealt with the subject in two sections: the supply of fuel in the appropriate quantity, and the atomisation of fuel preparatory to evaporation and combustion. Under the first heading, Dr. Watson considered the effects of some of the numerous variables on the amount of fuel required, and then described systems for controlling the supply. He said that, up to date, there had been no real success in designing a fuel system which, for a given setting of the pilot's control, would maintain a constant engine speed under all conditions. It should be noted, however, that the pilot was probably more interested in aircraft speed or thrust at a given altitude than in engine speed *per se*. In this country, it had been general to define the fuel flow in terms of altitude and the position of the pilot's control. In general, this involved the use of a metering orifice and the maintenance across it of a specific pressure drop. Of the eight possible methods of controlling fuel flow on this basis, the author described two which were in use or in course of development, namely, pressure-control systems in which the burners perform the function of metering orifices, and flow-control systems in which a separate metering orifice is employed. The atomisation of the fuel was generally achieved by means of a swirl-type atomiser. The author gave the law of discharge for such an atomiser, and after considering the nature of the spray, the factors determining the size of droplets, and the distribution of droplet sizes, he described the design of some atomisers. Mr. Herbert Sammons, in opening the discussion, referred to the differing requirements for propeller gas-turbines and jet gas-turbines, and, by comparison with the simpler requirements of Diesel engines, the problem of ensuring accurate distribution of fuel to the combustion chambers. This was also associated with the difficulty of ensuring a perfect distribution of air flow. Professor O. A. Saunders referred to methods of overcoming the comparatively high fuel consumption of jet engines when cruising, the uncertainty regarding the nature of the atomisation process, and the possibility of vaporising the fuel, instead of atomising it. From the point of view of the range of control required in a turbo-jet engine to suit different altitudes, Mr. A. B. S. Laidlaw favoured air injection. This method would also be particularly suited to heavier fuels, such as Diesel oil. Mr. I. Lubbock referred to the incidence of combustion efficiencies of only 50 per cent. or under, when running at low speeds; and to the finer particle size produced by air atomisation. Several other speakers took part in the discussion, and, in conclusion, Dr. Watson said that Diesel-engine practice had been of value in the development of fuel systems for aero gas turbines.

BURNING OF BOILER FUELS IN MARINE DIESEL ENGINES

At the present time there is, perhaps, little to choose between the Diesel engine and the steam turbine for the propulsion of medium sized vessels; each has its own supporters and a good case can be made out for both classes of machinery. The situation would be altered radically, however, if boiler oil could be substituted for the high-grade fuels used in Diesel engines and the possibilities of doing this were discussed by Mr. John Lamb, O.B.E., in his paper "The Burning of Boiler Fuels in Marine Diesel Engines," which was presented before a meeting of the Institute of Marine Engineers held in London on Tuesday, December 9. Mr. Lamb introduced his paper by referring to the economies which would be effected by such a change and went on to give details of the method by which boiler fuels were used successfully in the Diesel engine of the Auricula, a 12-knot, single-screw tanker, one of a fleet operated by the Royal Dutch Shell Group. Before trials were carried out in the actual vessels, however, numerous experiments, were made with a single-cylinder engine which approximated closely to one cylinder of the Werkspoor-type engines installed in the Auricula. After slightly over a year's work, it was ascertained that boiler fuel could be used, provided it was both purified and clarified in centrifugal-type separators and maintained at a temperature in the neighbourhood of 180 deg. F. Arrangements were made, therefore, to incorporate similar modifications in the fuel system of the Auricula, and several successful voyages were made during which boiler fuel was used. Mr. Lamb pointed out, however, that at first, running of the main engine on boiler fuel was confined to full-load conditions, arrangements having been made for switching to Diesel fuel during slow running and manœuvring. Early attempts at slow running on boiler fuel had resulted in carbonising of the fuel valves, and it was considered that this was due to loss of heat from the oil, coupled with reduced injection pressures. In view of the satisfactory performance at full load, further modifications were made to the fuel-oil heating and engine-cooling systems which enabled the temperature of the fuel oil at the main-engine injection-pump suctions to be maintained at 180 deg. F. during manœuvring and slow running and subsequent tests showed this arrangement to be satisfactory so long as the fuel-valve jackets were kept at 140 deg. F. After referring to the cost of converting existing engine installations to burn boiler fuel, Mr. Lamb gave figures of the wear which had occurred in the engine of the Auricula after 68,715 miles had been completed. These were compared with those for a similar vessel which had operated on Diesel fuel only, and it was shown that, so far as liners were concerned, the wear rates were identical; with regard to the general state of the engine, Mr. Lamb said that the conditions were similar to those that would be expected had the engine been operated on Diesel fuel. In closing, Mr. Lamb stated that, although the experiments had been confined to one type of engine, he saw no reason why similar results should not be obtained with other types of four-cycle or even two-cycle engines.

THE COLLEGE OF AERONAUTICS.

In October, 1943, the then Minister of Aircraft Production (Sir Stafford Cripps) appointed an Interdepartmental Committee, under the chairmanship of Sir Roy Fedden, "to prepare and submit detailed proposals for the establishment of a School of Aeronautical Science" on the lines of recommendations previously made by the Aeronautical Research Committee. The Committee duly reported in 1944, proposing the eventual provision of a very comprehensive college, but, in view of the time and expense involved in implementing the complete scheme, they also proposed the establishment of a smaller establishment, as a first step which could be taken without undue delay and at a relatively moderate cost. As a result, there was brought into being the present College of Aeronautics at Cranfield, Bedfordshire, to which the Minister of Education (the Rt. Hon. George Tomlinson, M.P. paid his first official visit on Monday, December 8. The College is situated at the former Royal Air Force

station at Cranfield, about ten miles south-west of Bedford, and consists of an extensive range of buildings converted from hangars, barrack blocks, etc. It is under the supervision of a Board of Governors, under the chairmanship of Air Chief Marshal Sir Edgar Ludlow-Hewitt, G.C.B., who received the Minister and guests; and the Principal is Mr. Ernest F. Relf, C.B.E., F.R.S. The purpose of the College is to provide an engineering, technical and scientific training in aeronautics, of a post-graduate standard, designed (in the words of the College's descriptive brochure) "to fit students for leadership in the aircraft industry, civil aviation, the Services, education and research." All of the leading bodies and Government departments concerned in these several fields are represented on the Board of Governors. The syllabus covers a two-year course, and at the present time some 85 students are in residence; 50 of these are in their first year and 35 in their second, the College having commenced its instructional work in October, 1946. It contains at present three main departments—aerodynamics, aircraft design, and aircraft propulsion—but is equipped also to provide experience and instruction (and, to some extent, to undertake research) in physics, electronics, metallurgy, strength of materials, etc. Particular emphasis is laid on practical work in the laboratories and with wind tunnels, and aircraft construction is studied in examples of actual aircraft, including a Halifax bomber. The equipment is being extended considerably, so that students in the second year can be given facilities to specialise. Those who have already covered the equivalent of the first-year course elsewhere may be admitted to the College for the second-year course only. Further particulars are obtainable from the Registrar, whose postal address is College of Aeronautics, Cranfield, Bletchley, Buckinghamshire.

FILM ON "ATOMIC PHYSICS."

Messrs. G.-B. Instructional, Limited—the branch of the J. Arthur Rank Organisation, Limited, which concentrates on the production of educational films, have completed recently a five-reel film on the history and development of atomic physics, from the conception of the original idea of the atom to the most recent—or, at least, the post-war stages—of nuclear fission. The five parts can be shown separately or as one film, running for about 80 minutes. The first part is history dramatised, dealing with Dalton's atomic theory, Faraday's experiments in electrolysis, etc. Part II deals with the investigation of cathode rays and the discovery of the electron; Part III with the work of Becquerel, the Curies and Lord Rutherford, which is continued in Part IV with that of Sir James Chadwick, and of Cockcroft and Walton in splitting the lithium atom in 1932. Part V covers the more recent events, leading to Hiroshima and Bikini. Of particular interest are the interpolated scenes of Lord Rutherford and Sir J. J. Thomson—biographical shots taken years ago for quite different purposes, but so apt in their matter and so neatly introduced as to fit quite naturally into the sequence. Professor Einstein, Dr. J. D. Cockcroft and Professor O. Frisch also figure in the film. Of the complete production, it may be said at once that we do not recall any instructional film in which the skill and resourcefulness of the "animation" experts has been better demonstrated; but it is hardly suited for general showing—for which, indeed, it was never intended, the audiences envisaged being rather the students of technical colleges, members of professional institutions, etc. In this respect, the governing policy seems rather to have fallen between two stools; a film adapted to a technically-minded auditory does not need all the play-acting which constitutes much of Part I, whereas an audience which requires to have its history garnished with histrionics is likely to lose the thread of the technical and scientific sequences long before Part V is reached. Without going so far, therefore, as to indulge in the hyperbole associated with a Hollywood film *première*, we do strongly advise all who are interested in current nuclear physics to take the first opportunity to see this film; readers of ENGINEERING who have been following the articles by Professor Soddy (whose work is mentioned by Rutherford in the film) should find it of particular interest.

OBITUARY.

MR. R. P. SLOAN, C.B.E.

MR. R. P. SLOAN, whose death we regret to record took place at Nice on Saturday, December 6, at the age of 73, was one of the pioneers who under the inspiration of C. H. Merz did so much to develop the employment of electric power on a large scale in this country. He was particularly associated with electricity supply on the North-East Coast, where the experience gained with an integrated system covering a large area proved most useful when the details of the national grid were being worked out.

Robert Patrick Sloan was born in Aberdeen in 1874, and was educated at Watson's College and the Heriot-Watt College, Edinburgh. He subsequently attended Finsbury Technical College, London, and was then employed at the Woolwich works of Messrs. Siemens Brothers and Company, Limited. He remained in the employment of this company for some years until, in 1901, he joined the recently formed firm of consulting engineers, Messrs. Merz and McLellan, at Newcastle-upon-Tyne, as chief assistant. Three years later, he was appointed manager of the Newcastle-upon-Tyne Electric Supply Company, which at that time was supplying power in part of the city, as well as in a small adjacent area. Shortly afterwards, however, expansion began by the acquisition of certain areas belonging to the Northern Counties Electricity Supply Company, while, in 1908, an arrangement was made with the Cleveland and Durham Electric Power Company for an interchange of power, whereby the total area covered was increased from 375 to 1,400 square miles. In 1904, the Carville station was opened with the then large capacity of 50,000 h.p., from which power was transmitted at 20 kV to all parts of the area. An important feature of the development was the linking-up of the collieries, coke-ovens and blast-furnaces with the transmission system, so that their waste heat could be utilised for electrical generation and thus supplement the output of the power stations. Later, further capital generating stations were built at Dunston and North Tees. The primary transmission pressure was also raised to 66 kV, and the network was largely expanded, so that when Mr. Sloan, who had been appointed a director of the North-Eastern Electric Supply Company in 1915 and chairman and managing director in 1921, retired in 1946, the area served amounted to 5,640 square miles and the annual output to 1,814 million kWh, compared with about 10,000,000 kWh 43 years earlier.

Mr. Sloan was appointed a Commander of the Order of the British Empire in 1919. He was elected a member of the Institution of Electrical Engineers in 1910, and served as vice-president of that body. He had been president of the British Electrical and Allied Industries Research Association, of the Incorporated Association of Electric Power Companies, and of the British Electrical Development Association. He was appointed a member of the Central Electricity Board in 1936.

RECONSTRUCTION OF ELECTRICAL WORKS AT TYSELEY.—In November, 1940, the electrical-accessories works of Messrs. J. H. Tucker and Company, Limited, King's-road, Tyseley, Birmingham, 11, were almost completely destroyed by enemy action. Thereafter, production was carried on in garages, sheds and other premises as widely separated as Minworth, Aberystwyth and Bridgend. A new works and administrative block, however, have now been built on the old site and these were formally opened by the Lord Mayor and Lady Mayoress of Birmingham on November 22. A bronze plaque commemorating the occasion was unveiled.

INSTITUTE OF WELDING.—The Council of the Institute of Welding have accepted the offer of the British Oxygen Company, Limited, to provide a prize of 100*l.* a year for three years, to be known as the B.O.C. Welding Prize, and to be awarded for a paper submitted by a member of the Institute on some aspect of gas welding. The terms of the competition, which are to be drawn up by the Institute, will be announced shortly. The Council have awarded the Sir William J. Larke Medal and a Prize of 50*l.*, to Mr. J. C. MacKain, A.M.I.Struct.E., A.M.Inst.W., of Edinburgh, for a paper on the evolution of welded components in house construction and welded bunkers for power houses.

FIFTY YEARS DEVELOPMENT OF THE SULZER DIESEL ENGINE.

THE connection of Messrs. Sulzer Brothers, of Winterthur, Switzerland, with the Diesel engine may be said to date from a period even before its inception, as in 1879, Rudolf Diesel, then a young man, entered the Winterthur shops in order to obtain practical shop experience. No doubt as a result of this early connection, a temporary agreement was entered into with Diesel in 1893, under which the firm secured the right to the Swiss patent for his engine. Work on the first engine built was started in 1897, so that the present year represents the jubilee of manufacture. The four years between the securing of the patent rights and the building of the first unit were spent in development work on the details of design. The engine was of the four-stroke type, having a single cylinder 260 mm. in diameter, a stroke of 410 mm., and developing 20 brake horse-power at 160 r.p.m. A final agreement between Diesel's German company and Sulzer Brothers, in 1903, assigned the latter exclusive Swiss patents, with the right to export to any country. The first order for twelve 35-h.p. engines was received from the Diesel Engine Company, of London, in the same year.

When this stage had been reached, it was decided that extensive commercial development could be undertaken and the manufacture of engines in series was put in hand. The first basic unit was a single-cylinder engine of 40 h.p., termed by the firm the D type. This was built as one-, two- and three-cylinder units, the latter having an output of 120 h.p. Progress was rapid, and within 3½ years, engines with twelve different cylinder diameters were in production, the largest having a rating of 200 h.p., or 600 h.p. for a three-cylinder engine. By 1910, four-cylinder engines, with outputs up to 1,000 h.p., had been built. The D-type engine was a heavy slow-speed long-stroke type which proved very reliable in service. The earlier models had trunk pistons, and piston cooling was not employed even in the larger sizes. Later, when piston spray-cooling with telescopic tubes had been developed for two-stroke engines, the same arrangement was employed for large four-stroke engines also. The main modification which took place in the development of the D-type engine was in connection with the injection-air pump. Originally, this was of single-stage design and took pre-compressed air from the engine cylinder through an overflow valve in the cylinder cover. Later, a two-stage pump was used, and proved so much superior that it was fitted to all engines, including those already delivered. Regulation in the early engines was limited to alteration of the fuel-pump charge, but later control by the governor of the air-pump and injection system was introduced.

From the early years, Messrs. Sulzer Brothers were convinced of the potentialities of the two-stroke engine and it was studied from the beginning of work in the Diesel-engine field. The first stationary two-stroke engine was built between the years 1906 and 1908. Parallel with the introduction of this class of engine, however, the four-stroke type was further developed. The slow-speed "D" type had been entirely successful, but a demand for a lighter high-speed unit gradually arose. This was met by the design of the "K" type, the first example of which was produced in 1910. This was of low compact construction. An example of the actual performance of a "K" engine which may be quoted refers to two 600-h.p. engines, running at 215 r.p.m., supplied to the Colombo Electric Tramways and Lighting Company in 1915. In 1922, they were still giving "splendid service" after 30,000 hours running.

The first stationary two-stroke engine, mentioned above, was not the first Diesel engine of this type built by the firm, as a 90-brake horse-power four-cylinder two-stroke marine engine was built in 1905. Stationary and marine engines were produced concurrently, but in giving a brief account of development in the Diesel engine field as a whole it will be a convenience to deal with the stationary and marine types separately, following with some account

of work in the sphere of rail traction, which was the latest of the three classes of application to be exploited. The first Diesel locomotive was put into trial service in 1912. The first two-stroke stationary engine was a three-cylinder trunk-piston unit, developing 750 brake horse-power at 150 r.p.m. The scavenging and charging air entered the cylinders through valves in the cylinder covers, the exhaust gases emerging through ports distributed over the whole circumference of the cylinder. The exhaust ports were controlled by the working cylinder and the scavenge valves by levers from a camshaft. Piston cooling was by spray, through telescopic tubes. Engines of the same type, ranging up to 2,000 brake horse-power, were built during the following four or five years, the last being produced in 1910.

After that time, a new scavenging system was introduced. This had been developed for marine work, the first engines embodying it being two 380-brake horse-power units installed in the Italian mail boat Romagna in 1910. Its application to land engines was a further illustration of the connection existing between marine and stationary developments. In the new scavenging system, two rows of scavenge ports are arranged, one above the other, on one side of the cylinder, and one row of exhaust ports on the other. The upper scavenge ports are controlled by a double-beat valve, which closes during the expansion stroke so that the exhaust gases cannot pass through them into the scavenging receiver. When the piston has uncovered the exhaust ports, however, it also uncovers the lower scavenge ports admitting the scavenge air. At the same time, the double-beat valve opens the upper scavenge ports, so that scavenging air flows into the cylinder through both sets of scavenge ports and sweeps the exhaust gases out through the exhaust ports. On the compression stroke, the lower scavenge ports are first closed by the piston and after them the exhaust ports. The upper scavenge ports, however, remain open, so that extra charging air passes into the cylinder. The double-beat valve is closed when the piston has passed the upper scavenge ports. With this arrangement, the engine output is increased in proportion to the quantity of extra charging air and the form of the cylinder cover is greatly simplified.

The first stationary engine in which this new scavenging system was employed was built early in 1912. It was a four-cylinder crosshead engine developing 1,500 h.p. at 150 r.p.m., and was followed in the same year by a 3,750-brake horse-power unit running at 132 r.p.m. This engine was installed in Harland and Wolff's Belfast shipyard. A notable installation of engines of this type consists of six, of 2,900 h.p. each, supplied for the Broken Hill mines in 1931. A few years later, further 3,200 h.p. and 1,200 h.p. units were supplied, and an order for five additional engines was received last year. In 1924, Sulzer Brothers turned their attention to the development of double-acting Diesel engines and built an experimental single-cylinder model with a piston diameter of 900 mm. Several commercial engines of this type were built, including an eight-cylinder 13,700-brake horse-power unit for a Shanghai power station. The greater part of the output, however, still consisted of D- and K-type engines, the designs of which were gradually modified so that components could be used for either type.

The whole of the engines so far mentioned were fitted with injection-air compressors, but work on airless injection had been carried out as early as 1915. A few engines of this type were built in 1921, but the first serial manufacture dates from 1926, when a range of light high-speed four-stroke units was introduced. The largest engine was of 600 brake horse-power, but by 1933, 2,550 h.p. had been reached. These engines were mostly supplied to Rumania, South America, Australia and India. The use of airless injection was then extended to two-stroke engines, the first unit of this type being a six-cylinder 3,200-h.p. engine supplied for the Broken Hill power station in 1937. It was so successful that the six air-injection engines previously supplied were converted to direct injection. As already mentioned, five further engines are on order for this station, which, in its extended form, will have a total capacity of 36,900 brake horse-power.

Two other stages in development should be mentioned before passing to some account of work in the marine field. The first was the supercharging of four-stroke engines, which improved their position relatively to the two-stroke type. Work in this field dates from 1933 and shortly after that time, in 1936, a licence agreement was concluded with the Büchi Syndicate. The other development was in connection with the use of inferior fuels in Diesel engines. The matter was of importance to the firm in the early days of the Diesel engine, owing to the high duties on imported petroleum products in both France and Germany. Diesel himself had attempted to use tar oil in 1899, but with no success. An experimental engine built by Sulzer Brothers in 1908, ran well on tar oil at full load, but had to be started with Diesel oil. At low loads it was not satisfactory, a special ignition-oil injecting device was designed to deal with the starting problem and, following other improvements, several engines were built and supplied to Mexico and South America. These, however, operated on crude oil. Altogether, a total of 42,000 brake horse-power of engines equipped with ignition-oil apparatus was built between 1910 and 1920, but reduction in the price of Diesel oil ultimately eliminated the necessity for using tar oil.

The total number of stationary Diesel engines built by Sulzer Brothers, or their licensees, up till the end of 1946, was over 5,000. This achievement in the fifty years with which this article is concerned was accomplished in parallel with remarkable progress in the marine field. The success in this latter sphere is evidence of striking ability and enterprise in a firm located in a non-maritime country. The first ship installation, dating from 1904, was for home waters. It consisted of a two-cylinder four-stroke 40-h.p. stationary-type engine fitted to the Venoge, a freighter plying on the Lake of Geneva. The engine was non-reversing and electric transmission was used. This equipment remained in service for 20 years, but the electric reversing system was complicated compared with the directly-reversing steam engines with which other lake vessels were equipped. In the year following the Venoge installation, a directly-reversible marine engine was produced. This was of the two-stroke type, and the two-stroke cycle has since been retained by the firm for all marine engines. The engine was of the type described above in connection with stationary engines, the scavenging air entering the cylinder through valves in the cover, the exhaust gases being led off through ports situated around the bottom circumference of the cylinder and controlled by the working piston. The opening times of the scavenging valves were the same for both directions of rotation, and reversing was carried out by control of the fuel and starting valves.

The early marine engines were of this uniflow scavenge type, but, in 1909, the double-row scavenge ing system, already briefly described, was introduced, the first marine engines of this type, of 380 brake horse-power, being fitted in the Italian mail boat Romagna in 1910. No great amount of running experience was obtained with these engines, as the vessel foundered, owing to faulty loading, after a short period of service. The installation, however, was followed up by a number of others of identical design and with outputs ranging from 100 brake horse-power to 450 brake horse-power. All were four-cylinder trunk-piston engines, with cylinder diameters ranging from 175 mm. to 310 mm. As extensive developments in the marine field necessitated considerably increased cylinder capacity, an experimental single-cylinder unit was built in 1910. The cylinder bore was 1,000 mm. and the engine developed 2,000 brake horse-power when running at 150 r.p.m. Successful experience with this engine permitted the building of larger marine sets to be undertaken with confidence. The first installation was on the Monte Penedo, of the Hamburg-South America Line. The twin four-cylinder engines each developed 850 brake horse-power at 160 r.p.m. This was the first ocean-going ship to be equipped with two-stroke Diesel engines. In 1914, two four-cylinder engines of 1,600 brake horse-power at 110 r.p.m., and with cylinder diameters of 680 mm., were built. Owing to the outbreak of war, however, these engines were never installed in a ship.

During the first great war, the activities of the firm were confined to marine engines of the smaller types, but in 1917 two four-cylinder engines with 600-mm. bore cylinders, and with an output of 1,350 brake horse-power at 125 r.p.m., were built. They were fitted with rotary valves in place of the double-beat scavenge valves previously used. These engines were installed in the m.s. Conde de Churruca, which was, at that time, the largest vessel to be equipped with Sulzer engines. The vessel has been renamed the Remedios and is still in service with the same engines, which were modernised in 1931. These sets were followed by others, of 680-mm. cylinder diameter, in 1919, and 760-mm. diameter in 1923. What may be described as a turning point in the history of the marine Diesel engines dates from 1924, when the 22,000-ton quadruple-screw liner Aorangi, of the Union Steamship Company of New Zealand, went into commission. The four engines, which were built by the Fairfield Shipbuilding and Engineering Company, to Sulzer designs, develop a total of 13,000 h.p. at 127 r.p.m. The cylinder bore is 27·5 in. This vessel covered more than 1·6 million nautical miles during her first 20 years of service.

As mentioned in connection with stationary engines, the building of a range of light airless-injection engines was put in hand in 1926; an output of 600 brake horse-power had been reached by that year, rising to 2,550 h.p. in 1933. Airless injection was generally adopted in the marine field from 1929, the general mechanical arrangements of the engines not being altered from the practice followed with air-injection engines. An outstanding example was furnished by the three 12-cylinder 12,500 brake horse-power units installed in the Dutch triple-screw liner Oranje in 1938. These are the largest single-acting two-stroke Diesel engines in service. In addition to the propulsion units, with a total output of 37,500 h.p., the vessel has also five auxiliary Sulzer Diesel engines of a total of 9,000 horse-power for the operation of the scavenging blowers and general purposes. The vessel, of 20,000 tons register, reached a speed of 26·3 knots on her trials. The engines of the Oranje have cylinders of 760-mm. bore, but in working out a standard range of high-power marine engines, cylinder diameters of 600 mm. and 720 mm. were adopted. Combinations ranging from four to twelve cylinders give outputs of from 1,500 brake horse-power to 10,000 brake horse-power.

The first double-acting marine engine built by the firm was installed in the Dutch cargo vessel Tajandoen in 1930. It was an eight-cylinder unit of 700-mm. bore and developing 7,000 brake horse-power at 106 r.p.m. As mentioned earlier, work on double-acting engines was started in 1924, when a single-cylinder experimental unit was built. The first commercial installation was a 2,400-brake horse-power engine supplied to a Swiss power station for standby purposes; it is still in service. The Tajandoen engine, however, followed closely in time. This marine set, as mentioned above, was rated at 7,000 brake horse-power, but a similar engine supplied to the electric power station at Fribourg, in Switzerland, and for which the speed was raised to 150 r.p.m., gave 10,800 brake horse-power. From about 1931, a number of licensee firms began to build double-acting direct-injection Diesel engines of Sulzer design. A notable installation was that for the Italian liner Saturnia. This consisted of two ten-cylinder 760-mm. bore engines running at 125 r.p.m., each with a nominal output of 12,000 brake horse-power. During the acceptance tests, one of these sets, running at 152 r.p.m., carried a load of 20,820 brake horse-power for 20 minutes. These engines were built by the Cantieri Riuniti dell'Adriatico, of Trieste.

Developments in the marine field during the recent war have included the design of a range of light high-speed trunk-piston engines for merchant vessels. These were first built in 1942 and are intended particularly to meet the requirements of Diesel-electric or geared-transmission propulsion. The engines are built with cylinder diameters of 320, 420 and 510 mm., giving outputs of from 600 to

5,000 brake horse-power at speeds ranging from 500 to 320 r.p.m. The engines are direct reversing, but for Diesel-electric plants they are supplied with locked reversing gear or may be built without reversing arrangements. In concluding this brief account of Sulzer's marine work, mention may be made of small and medium-sized engines intended for coastal and river vessels. From the outset of development in this direction, it was realised that simplicity was necessary, as supervision might be relatively lax and as the engines are frequently controlled from the deck. In view of these considerations air-injection was ruled out at once. In 1921, tests with direct injection on the precombustion-chamber system were carried out on a single-cylinder hot-bulb engine of the type which had been manufactured since 1916 for driving starting-air compressors. Following this work, a range of precombustion-chamber engines was put in hand; the cylinder output varied from 20 to 50 brake horse-power. The engines were of the trunk-piston type with crankcase scavenging, but in 1925 a new range of crosshead units was introduced, the lower sides of the pistons being used as scavenge pumps. In 1932, the precombustion chamber was abandoned and direct-injection introduced. The whole design was revised in 1942, in the light of accumulated experience, with the idea of further simplification and the reduction of necessary attendance. Present models are built with cylinder diameters of 240, 290 and 360 mm., and have outputs ranging from 225 to 2,000 brake horse-power.

Work in connection with rail traction dates from 1912, when a Diesel locomotive equipped with a two-stroke four-cylinder V-type engine, of 1,000 brake horse-power, was built. The engine acted on the driving axles directly, through coupling rods. Starting was by compressed air supplied from containers charged by an auxiliary Diesel set. The locomotive was put into trial service on the Prussian State Railways. It was not successful, the chief difficulty arising from the fact that the engine was so cooled during starting that ignition was very difficult. The overload capacity at low speeds of rotation was also insufficient. This locomotive represented the only attempt made to use direct transmission. Some consideration was given to the possibility of using change-speed gear, but it was finally decided that the electric drive offered the greatest possibilities of success, and, in 1914, five Sulzer Diesel-electric railcars, of 200 h.p., were built for the Prussian and Saxon State Railways. With the idea of sacrificing as little space as possible for the accommodation of the prime mover and transmission, the Diesel engines of these cars were housed in the bogie. It was also hoped that with this arrangement transmission of vibrations from the engine to the car body would be prevented. The design, however, was not altogether successful. The hunting movements of the bogie, with the added weight of the engine, resulted in lateral impacts on the rails, wheel flanges and axle-box guides which considerably increased maintenance costs, the engine was not easily accessible and was exposed to dirt, and vibrations were still felt in the passenger compartment.

The outbreak of the first world war interrupted the development of which these vehicles represented the beginning. Two of the railcars were bought back from Saxony and the engines converted to airless injection, and the compressed-air starting arrangement was replaced by electric starting from an accumulator. One of these converted machines was sold to a private Swiss railway and is still in operation. These five early railcars were fitted with four-stroke V-type engines, although Sulzer Brothers had developed a reversible two-stroke marine engine by 1905 and it might have been expected that it would have been adopted for the early work on rail traction. It was employed for the original direct-drive Prussian State Railway locomotive, but when the five Diesel-electric railcars were built, the four-stroke engine was adopted in view of its greater simplicity owing to the absence of scavenging arrangements. The more even torque of the two-stroke engine, which had been a consideration of importance in connection with the direct-drive locomotive, was of little importance in the case of the Diesel-electric machines, in which there was a double conversion of energy between the engine and the driving wheels. These considerations have determined the policy of the firm throughout their connection with Diesel traction for which four-stroke engines have been employed almost exclusively. The position of the four-stroke engine in this particular field has been strengthened by the introduction of pressure charging by means of a blower driven by an exhaust-gas turbine. This arrangement can be applied more simply to a four-stroke than to a two-stroke engine, the latter requiring special equipment and raising problems of regulation.

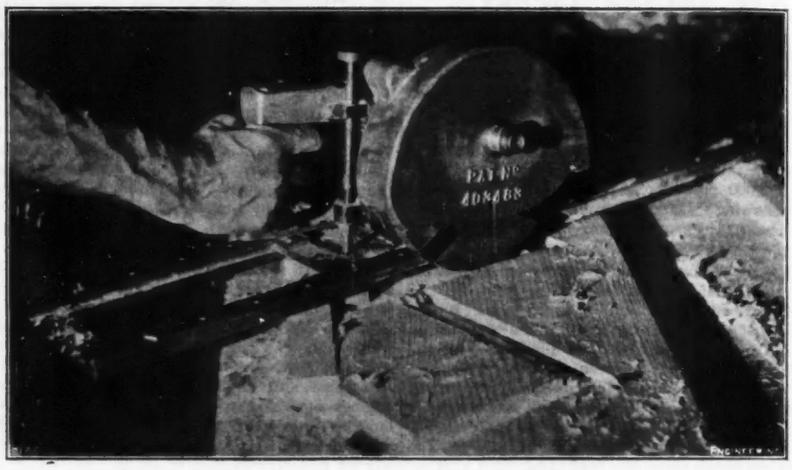
Two important conditions which have to be met in the design of Diesel engines for rail traction are low weight and small space requirements. There are various ways in which these conditions may be complied with, such as raising the mean effective pressure and speed and the employment of light-alloy metals. Experience and development also enable more effective use to be made of structural material. It is not possible here to deal in detail with the progressive design of the Sulzer rail-traction engine, but as an indication of the progress made it may be said that while the 200-h.p. engines of the railcars built in 1914 ran at 440 r.p.m., six-cylinder engines of 735 brake horse-power with exhaust-gas turbine pressure charging built in 1942, ran at 850 r.p.m. This raising of speed, together with increase in the mean effective pressure, has taken place gradually. In modern engines more effective use is made of material. The crankcase, which originally was of cast steel, is now welded and forms a single part with the auxiliary frame. The transverse walls of large engines are of cast steel and those of small engines of steel plate, in both cases being welded to the crankcase and forming a very rigid structure. The cylinder block is built up in the same way. Each cylinder has its own cover, fitted with one admission and one exhaust valve, and the light-metal pistons can easily be removed from above.

During the first 15 years of development, all traction engines were of the V-type, as this appeared to be the best way to obtain maximum output in terms of space occupied. For high-powered engines, however, in order to obtain the highest power-to-weight ratio for a given loading gauge, the double-row engine has proved superior. An example of an application of this development is furnished by two 4,400-h.p. Diesel locomotives supplied to the Rumanian State Railways and Société Nationale des Chemins de Fer Français. Each is fitted with two 2,200-brake horse-power engines with two parallel rows of six vertical cylinders acting on two parallel crankshafts which are connected by gearing, which also drives the electric generator at a somewhat higher speed. The main arguments in favour of the double-row engine are that the space available in the loading gauge is better utilised; that as the connecting-rod bearings are narrower than those of a V-type engine for the same stresses, the double-row engine is, in general, shorter than the V-type engine for the same output and crankshaft speed; the vertical cylinders are more convenient than the inclined ones from the point of view of maintenance; and the deep crankcase, carried well above the centre of the shaft, which is used in double-row engines and increases rigidity, cannot be used in V-type engines. In view of these considerations, the practice of the firm is to use double-row engines for all installations in which the required output cannot be obtained from six or eight cylinders. For smaller powers, a single-row engine is fitted, in view of its greater simplicity.

It is not possible here to refer in detail to the very large number of Diesel-electric railcars and locomotives supplied by Sulzer Brothers to many different countries, but as they form outstanding examples, some brief particulars may be given of the 4,400-h.p. locomotives supplied to the French State Railways and to Rumania. The former has a length of 33·05 m. over the buffers, a service weight of 228 tons, and a maximum speed of 130 km. per hour. It was put into service in the middle of 1938 and covered 225,000 km. up till the outbreak of war. It was out of service until the middle of 1945, but then went into operation again, and, by the end of 1946, had run 503,000 km. Less is known about the performance of the Rumanian locomotive. This has a length of 29·3 m., a service weight of 230 tons and a maximum speed of 100 km. per hour. It is operated on a difficult mountain line. From the middle of 1938 to the middle of 1940, it had covered a total distance of 180,000 km.

PORTABLE WOOD-GROOVING MACHINE.

MESSRS. HAYDICK HANDY HOUSER COMPANY, LIMITED, BATH.



PORTABLE WOOD-GROOVING MACHINE.

ALTHOUGH power-operated hand tools are now commonplace items of equipment in almost every engineering workshop, it is, perhaps, not always realised that a range of power-operated hand tools for woodworking, such as circular saws, sanding machines and planers, is now available. These tools have many useful applications and an interesting newcomer to the range is the Haydick portable houser, which is manufactured by Messrs. Haydick Handy Houser Company, Limited, 2, Victoria-place, Grosvenor, Bath, for the sole concessionaires, Messrs. Equipments, Limited, Northwood, Middlesex.

The machine is illustrated on this page and it can be used for a variety of grooving and moulding operations that cannot be performed by other machines. As will be seen from the illustration, the machine is fitted with a circular cutter-head which rotates in the vertical plane, the cutters being clamped in slots formed in the cutter-head and projecting beyond its periphery. The cutter-head is keyed to the end of the armature shaft of a ¾-h.p. 200-250-volt universal motor, the shaft rotating in ball bearings at the cutter end and in roller bearings at the end remote from the cutter, the object being to allow for any slight expansion of the shaft which may

occur during working. The motor is housed in a cast aluminium-alloy body and the complete body is hinged at one side to a separate bedplate, the sides of the bedplate being arranged to slide in grooves formed in the internal vertical faces of the guide rails visible in the illustration. The depth of cut is adjusted by swinging the complete body of the machine about the hinge, for which purpose an adjusting screw is provided which passes through threaded lugs formed in the side of the body remote from the inge and abuts against the bedplate. Once the desired depth of cut has been obtained, however, the adjusting screw can be locked; the maximum depth of cut obtainable is $\frac{1}{4}$ in., and the maximum width 2 in. A useful feature is the provision of a brake which enables the operator to stop the machine in approximately 6 seconds. The brake acts on the outside vertical face of the cutter-head and is operated by the push-button control visible in the illustration.

The guide rails in which the unit slides are 3 ft. long and when the machine is in operation they rest on packing pieces; this arrangement can be seen in the illustration, which shows the machine being used for cutting the housings in a stringer for stair treads and risers. Perhaps the main advantage of the machine is that an exceptionally clean groove can be cut across the grain. This is due, partly to the high speed of the cutter, which is about 6,000 r.p.m., but mainly to the fact that the cutter is arranged to cut into, and not out of, the wood. It is, therefore, particularly suitable for manufacturing such items as racks for pipes and the preparation of wooden strips for making into grilles. Obviously, in such applications the grooves are formed in a comparatively wide piece of wood which is cut subsequently on a slitting saw into strips of the required width. The machine can be used also for halving and tenoning, and in the latter application the wood is turned over so that both sides of the tongue can be cut; should the length of tongue exceed 2 in., the machine's maximum width of cut, then two or more passes can be made. If required, a small circular saw can be fitted in place of the cutter head, and the machine can then be used for cross-cut and taper sawing.

THE ENGINEERING CENTRE, GLASGOW.

THE official opening, on December 3, by Sir James Lithgow, Bt., of the Engineering Centre at 351, Sauchiehall-street, Glasgow, inaugurated an industrial venture which is believed to be unique in the British Isles so far as the engineering industry is concerned. The Centre provides a permanent exhibition of engineering products, tools and materials, with an expert staff and facilities for arranging, between manufacturers, for the utilisation of spare productive capacity. While its primary purpose is the promotion of sales, and its accommodation and services for home and overseas buyers are particularly stressed, it will provide also a meeting place for technical societies, and for the display of special exhibitions. It is stated that more than 150 firms exhibited on the opening day; and, although Sir James Lithgow remarked on the absence of certain classes of manufactures, of which the respective trade associations were accustomed to hold their own periodical exhibitions, he expressed the hope that these classes also might be represented among the exhibits in due course. At present, mechanical and hydraulic engineering items are arranged on the ground floor and the lighter industries on the first floor; but it is hoped to open an exhibition of boilers and other heavy-engineering products in the basement in January, and an electrical section in February.

At the opening ceremony, which was attended by a large number of representatives of the universities and technical colleges, Government departments, municipalities, and of the engineering industry, Sir James Lithgow was introduced by Major Jackson Millar, C.B.E., chairman of the Centre, who briefly explained its objects and scope; up to date, he said, some 80,000*l.* had been expended on this endeavour to provide a shop window for British engineering products. Every effort would be made to keep the exhibition up to date and useful. Sir James, in declaring the Centre open, said that it would attract four main classes of visitors: the manufacturer, the buyer, people who were interested enough in engineering to wish to extend their knowledge of it, and the public at large, who should find increasing attraction in an industry with which their general well-being was so closely bound up.

Mr. E. Bruce Ball, M.A., replying on behalf of the Centre, emphasised Major Millar's declaration that the exhibition should present only the most modern engineering developments. They were determined, he said, not to allow the Centre to become merely a museum; firms would be asked to keep their exhibits continually up to date. The Centre had received very influential support from all parts of the country, and was sponsored also by 36 of the leading institutions and trade associations.

LABOUR NOTES.

THE agreement on the subject of wages recently negotiated by representatives of the National Coal Board and representatives of the National Union of Mineworkers has been unanimously approved by the various area organisations. The principal increases are one of 15*s.* a week for adult underground workers, one of 10*s.* a week for adult surface workers, and appropriate additions for piece workers and juveniles; the changes are having effect as from the first full pay week in November and their cost is estimated at about 13,000,000*l.* a year.

In the week which ended on November 29, absenteeism in the British coal-mining industry was slightly higher than in the previous week—13·02 per cent., as compared with 12·81 per cent. Voluntary absenteeism among face workers was 7·27 per cent., as compared with 6·86 per cent. The total labour force increased by 900, and face workers by 200. Recruitment is still catching up on wastage.

Mr. James Griffiths, the Minister of National Insurance, announced in the House of Commons last week that an Industrial Injuries Advisory Council had been appointed to advise on questions relating to the National Insurance Industrial (Industrial Injuries) Act, 1946. The members of the council are:—Sir William Garrett (chairman), Mr. J. H. Allen, Mr. J. Bradshaw, Mr. E. de'Ath, Mr. D. C. Happold, Professor R. E. Lane, Mr. Will Lawther, Mr. T. A. E. Layburn, Alderman D. B. Lewis, Dame Anne Loughlin, Mr. John Megaw, Mr. H. W. Naish, Mr. E. A. Nicholl, Mr. Alfred Roberts, Mr. Clifford Trollope, and Mr. Frank Wolstencroft. Another woman has still to be appointed. The members are to hold office for three years.

The Ministry of Labour and National Service is to apply for the release from the Forces of men formerly employed on the production of coal-mining machinery. Only fully-skilled men and apprentices, who were in the final year when called up to the Forces, are eligible for release. Applications will not be made for men called up after the end af 1946. The number of releases for which each firm may apply is to be limited to the number of first preference vacancies which exist for skilled men.

At a meeting of shop stewards held after he had inspected the works of an important railway-carriage works in Birmingham, Mr. J. H. Jones, Joint Parliamentary Secretary to the Ministry of Supply, said that the ordinary man in the factories did not yet seem to have realised his own importance in the economic crisis. "I saw," he added, "about 200 of them knocking off at seven minutes to 11 this morning. I am not complaining unduly about this, but 200 times the loss of seven minutes means the loss of a lot of work, and the country just cannot afford it. If seven minutes were deducted from their pay packets, they would be the first to run with a complaint to the union. Within the next few months the country will be in the middle of the most intensive competition for world markets it has ever seen."

A note in the official *Trade Report* of the United Patternmakers' Association deals with the subject of the shortage of hand tools. "I think," Mr. Beard, the general secretary, said, "that this question should be dealt with by the Government Department concerned as one of urgency. If it is expected that production is to be maintained by our members, they must have tools for the job, and there appears to be no reason why most of these hand tools could not be provided in greater quantity. While on this question, I make passing reference to the theft of tools. These thefts are increasing, and I have written the employers on the question to see if we cannot obtain greater security and some assistance in replacement when such losses occur."

In a letter on this subject sent to Mr. Ellis Smith, M.P., the president of the United Patternmakers' Association, Mr. J. H. Jones, Joint Parliamentary Secretary to the Ministry of Supply, says that there is unfortunately a general shortage of paring gauges, spoon gauges, and similar tools, "and no immediate improvement in the supply position can be expected." "Arrangements have been made, however," Mr. Jones adds, "with the Manufacturers' and Distributors' Trade Associations for supplies to be directed to those areas in which acute local shortages are brought to our notice, and they are being asked to arrange for an increased distribution . . . as soon as possible."

At the end of 1946, the total membership of British trade unions was approximately 8,714,000, as compared with 7,813,000 at the end of 1945. The number of males at the end of 1946 was 7,139,000, showing an increase of 925,000 as compared with the previous year, and the number of females was 1,575,000—a decrease of 24,000. The total of 8,714,000 included 44,000 members in branches in Eire, and 85,000 in other branches outside the United Kingdom. Excluding the members of these overseas branches, the total membership (inclusive of members serving with the Forces) was thus about 8,585,000 at the end of 1946, as compared with 7,686,000 at the end of 1945; of these totals, the membership in Northern Ireland accounted for 169,000 and 148,000, respectively.

In the industries covered by the statistics regularly compiled by the Ministry of Labour and National Service, the changes in rates of wages reported to have come into operation in the United Kingdom during October resulted in an aggregate increase estimated at approximately 148,000*l.* in the weekly full-time wages of about 415,000 workpeople. In addition, a number of workpeople had their hourly rates increased, so as to give approximately the same weekly wage as before for a shorter working week.

The principal groups of workpeople affected were agricultural employees in Scotland; in the retail drapery, outfitting, and footwear trades in Great Britain; in the retail grocery and provision, etc., trades in England and Wales; in milk distribution in England and Wales; in the bacon-curing industry; and in the warehouses of the manufacturing section of the cotton industry. In the ten months, January to October, inclusive, 1947, 3,240,000 workers received wage increases amounting to a total of 1,018,000*l.* In the corresponding months of 1946, 7,300,000 received increases totalling 2,600,000*l.*

Of the total increase of 148,000*l.* in October, 1947, about 62,000*l.* was the result of arrangements made by Joint Industrial Councils or other joint standing bodies established by voluntary agreement; about 58,500*l.* resulted from Orders made under the Agricultural Wages Regulation Acts and the Wages Councils Acts; about 27,000*l.* was the result of direct negotiations between employers and workmen or their representatives; and the remainder was the result of arbitration awards.

The changes in hours of labour reported to have come into operation in October resulted in an average reduction of about 2¾ hours a week for about 310,000 workpeople. The principal groups of workpeople affected were those employed in electricity-supply undertakings, whose normal weekly hours were reduced from 48 to 44 for shift work and from 47 to 44 for day work; those employed in the retail drapery, outfitting, and footwear trades in Great Britain, and the retail grocery and provision, etc., trades in England and Wales, whose hours in respect of which the minimum weekly rates of wages are payable were reduced from 48 to 46; those employed in glass-container manufacture, whose normal working week for other than shift work, was reduced from 48 hours or 47 hours to 45 hours; those employed in the iron and steel and non-ferrous scrap industry, whose working week was reduced from 48 to 44 hours; those employed in the making of packing cases and wooden containers, whose working week was reduced from 47 hours to 44 hours; and those employed in the manufacture of gelatine and glue, whose working week was reduced from 48 hours to 44 hours. During the ten completed months of 1947 changes in hours of labour reported to have come into operation in the industries covered by the statistics compiled by the Ministry of Labour and National Service resulted in an average reduction of about 3½ hours a week for about 5,000,000 workpeople.

The number of industrial disputes leading to stoppages of work in the United Kingdom, reported to the Ministry of Labour and National Service as beginning in October, was 168. In addition, seven stoppages which began before October were still in progress at the beginning of that month. The approximate number of workpeople involved, during October, in these 175 stoppages, including those thrown out of employment at the establishments when the stoppages began although not themselves parties to the disputes, was estimated at 73,000. The aggregate number of working days lost at the establishments concerned, during October, was about 213,000. Of the stoppages of work through industrial disputes known to have been in progress at some time in October, the coal-mining industry accounted for 100, involving nearly 46,000 employees and resulting in an aggregate loss of about 130,000 working days.

FLOW OF BOILING WATER THROUGH NOZZLES, ORIFICES AND PIPES.*

By J. G. BURNELL, B.E., M.I.C.E.

HOT water at a temperature corresponding to its boiling point (conveniently designated "saturated water") has frequently to be handled through valves, traps, and pipes. Familiar examples are blow-down from a boiler, the flow of hot water to and from steam traps in industrial heating processes, and the passage of condensate through piping and traps draining a series of heaters connected in cascade for the regenerative heating of feed water by means of steam bled from the various stages of large steam turbines. In cases such as the latter, a reasonably accurate knowledge of the laws of flow of hot water is necessary, and the size of pipe needed to pass a large flow of low-pressure drainage is at first surprising.

The first writer to deal with the subject of the flow of hot water at temperatures near its boiling point was Professor Rateau,† who showed how the flow of hot water through a nozzle can be calculated by use of the entropy-temperature diagram; that, for any given initial saturation pressure, there is a critical throat pressure for which the discharge is a maximum, and that no increase of flow occurs for any decrease of back pressure below this critical pressure, just as for the flow of steam. Rateau also pointed out that, for a given initial pressure, the discharge through the nozzle would increase for each degree of temperature by which the water was initially below saturation temperature, until the initial temperature reached that corresponding to saturated steam at the back pressure. Below this initial temperature the usual laws for fluid flow apply.

A notable advance in the knowledge of the flow of saturated water was made by W. T. Bottomley.‡ He corrected and extended Rateau's thermodynamic expressions governing the flow in nozzles and made several accurate measurements of the flow through nozzles of the condensate drains from a full-size evaporating plant. In addition, he formulated expressions covering the flow of saturated water in pipes, measured the flow and pressure gradient in a pipe carrying the hot condensate discharged from a nozzle; he also demonstrated the agreement of his equations with the result. For the flow through nozzles, his measured maximum discharges obtained under a very slight head, just sufficient to prevent entrained steam passing, are from four to five times as great as would be expected from the ordinary thermodynamic theory. He found, however, that if the saturated water reaches the nozzle at a rate less than the maximum rate of discharge, the flow accommodates itself to this lower discharge by an almost imperceptible drop in the water level about the nozzle, permitting slight unsealing. The amount of steam passed, however, does not exceed ½ per cent., even for a flow half that of the maximum. This extraordinary self-regulation extends over the whole range of flow down to the theoretical for ideal expansion. The explanation of this curious phenomenon will be given later.

A series of experiments determining the flow of saturated water through sharp-edged orifices was carried out by M. W. Benjamin and J. G. Miller.§ These experiments relate only to sharp-edged orifices and were made with apparatus allowing variations of initial and back pressure and of static head above the orifice. Steam could also be passed along with the water through the orifice. Their conclusions are as follows.

"When saturated water flows through a sharp-edged orifice no flashing occurs until after the water is through the orifice, and, contrary to the theory based on a change of state, no critical-pressure condition is evident. The quantity of saturated water that will flow through a sharp-edged orifice for given pressure conditions can be calculated with sufficient accuracy by the formula used to determine the flow of cold (70 deg. F.) water through an orifice, and the discharge coefficients found for saturated water are approximately the same as those generally used for cold water. When calculating the flow of saturated water through an orifice it is important to remember that the value of the head to use in the formula is the equivalent head in feet of water, based on the pressure drop across the orifice and the density of the saturated water.

"When a mixture of saturated steam and water flows through a sharp-edged orifice with given initial and back pressures, a small variation in the amount of steam in the mixture, within the range of 0 to 4 per cent., has a considerable effect on the total weight of mixture and, consequently, on the weight of saturated water flowing through the orifice. By this means the weight of mixture passing the orifice may be reduced approximately to 40 per cent. by passing 4 per cent. of steam. For mixtures in which the quantity of steam is greater than 4 per cent., a small increase or decrease in steam content has only a slight effect on the total weight of flow."

The formula for maximum flow is:—

$$\frac{\text{M lb. per sec.}}{\text{X sq. ft. of orifice}} = 0{\cdot}6\,\rho\sqrt{\frac{2g}{\rho}\times(P_1 - P_2)}, \quad (1)$$

where the pressures P_1 and P_2 are in lb. per square foot, ρ = density of saturated water at P_1, in lb. per cubic foot, and 0·6 is the usual coefficient of contraction for a sharp-edged orifice.

From the results it is clear that, for the range of initial pressures used (up to 250 lb. per square inch), no critical pressure exists in the orifice. In other words, change of state does not occur within the orifice. Photographs show the mixture of water and steam leaving the downstream face of the orifice. Down to back pressures of about half initial pressures, the jet persists for a short distance downstream, but with lower back pressure it breaks up almost instantaneously. At low back pressure, the discharge of an orifice will approximate to that of a nozzle, the contractions of the orifice jet being balanced by the critical pressure effect in the nozzle.

For measurements of the flow of saturated water through nozzles and combinations of nozzles and pipes, the equipment shown in Fig. 1, opposite, was used by the author for pressures up to 40 lb. per square inch gauge. Water contained in a vertical cylindrical vessel, provided with end covers and fitted with a long gauge glass, was kept boiling by steam admitted through a Hydrokinetor near the bottom. The boiling water passed out by a nipple, fitted with a thermometer, to the nozzle and thence to a condenser. Where tests were being made of combinations of nozzles and pipes or of pipes only, manometers were connected along the pipe, as seen in Fig. 1.

Before starting a test, the vessel was filled with water, which was boiled vigorously by steam admitted to the bottom through the Hydrokinetor. When the temperature was steady, a valve on the discharge pipe beyond the nozzle was opened and the rate of fall of the water level in the vessel was carefully noted, readings being taken generally from 36 in. to 2 in. above the nozzle at 6 in. intervals. Knowing the diameter of the vessel (19⅛ in.) and the temperature and consequent density of the water, the corresponding flow, in lb. per second per square foot of nozzle area, can be calculated. Discharges calculated for each 6 in. of fall were plotted against the static head above the nozzle and a line drawn through these points to intersect the line $h = 0$, h being the head in feet. This gave the value of the discharge for $h = 0$ for the pressure used.

The nozzle used was of gunmetal, having a well-rounded entry and a throat diameter of 0·213 in. It was considered unnecessary to lag the vessel, the water temperature throughout the test being maintained constant by injecting ample surplus steam.

For the experiments in which the initial pressure was atmospheric, the top cover was removed and the pressure was as given by the barometer. For cases where the initial pressure was above or below atmospheric, the upper cover was replaced and the desired pressure was set by balancing the surplus steam admitted against the steady escape of vapour by a vent pipe to the condenser. The exact pressure was indicated on a mercury manometer. Usually, 20 minutes or so were needed to set the valves in correct adjustment.

For measuring the flow through the nozzle from pressures above 40 lb. per square inch gauge, boiling water was drawn from the drum of a water-tube boiler, passed through the nozzle and then through a heat exchanger, where the flash was condensed, and the flow measured by weighing the discharge over a suitable period to a 40-gallon drum on scales. Connection was made at the rear of the boiler drum by removing the flooding connection for the superheater and utilising this facing. After filling up the drum to a full glass, the feed pump was stopped and the test taken as the pressure slowly fell through the required pressure. By this means it was ensured that the water was at full saturation temperature.

The results obtained by the author are shown plotted in Fig. 2, on page 574, and the six discharges measured by Bottomley are also indicated. The lower curve marked "Calculated Adiabatic Flow $h = 0$" shows values for $\frac{M}{X}$ computed from the thermodynamic equations, assuming adiabatic flow and the initial static head, h, on the nozzle as 0. The method of computing the theoretical discharge is given in Appendix I.

Before going farther, it is desirable to consider how the coefficient of discharge of a nozzle can apparently vary from unity to four or five, while the coefficient of an orifice remains constant at its usual cold-water value of about 0·6. Consider, first, the equilibrium of a small vapour bubble in boiling water. We have—

$$P_v - P_w = \frac{2\sigma}{r} \quad . \quad (2)$$

where P_v is the pressure of the vapour inside the bubble (corresponding to the temperature of the water) and P_w is the hydrostatic pressure of the liquid outside, σ is the surface tension at the boundary of the bubble, and r its radius, c.g.s. absolute units being employed.

Equation (2) shows that, when water is boiling, its temperature must always be somewhat above that corresponding to the hydraulic pressure of the liquid. For a given $P_v - P_w$, there is a minimum size of bubble able to exist in the liquid. This will be referred to as a bubble of critical size for that condition.

De Luc found that he could raise the temperature of air-free water at atmospheric pressure to 234·5 deg. F. before boiling occurred. It then took place with sudden force, the phenomenon being known as "boiling by bumping." For this limit of superheating of the water, the ratio of appropriate saturation pressures is

$$\frac{14{\cdot}7}{22{\cdot}2} = 0{\cdot}66.$$

Compare this with the pressure drop corresponding to the measured discharge of boiling water (again air-free) through a nozzle. From Fig. 2 and Table I (4th column), the calculated pressure drop is $0{\cdot}33P_1$, assuming no vaporisation until the throat is reached. The ratio $\frac{P_{throat}}{P_1}$ is then 0·67.

For the flow of boiling water in a nozzle, it appears, therefore, that, with falling pressure, no vaporisation occurs; neither does the temperature drop until the exit pressure falls to about two-thirds of the initial saturation pressure, when sudden vaporisation occurs.

Callendar interpreted his experiments on the total heat of water as showing that water always contains its own volume of vapour in solution. Stated in another form, for a liquid in equilibrium with its vapour, high-energy vapour molecules are present at the same density in both liquid and vapour. As superheating increases—either by increase of temperature at constant pressure or by decrease of pressure at constant temperature—the number of high-energy vapour molecules in solution in the liquid rapidly increases until the critical point is reached. For an initial saturation pressure of 15 lb. per square inch, they will have increased 47·2 times when the critical point is reached. It is suggested that, at this stage, spontaneous generation of bubbles of critical size occurs owing to accidental meetings at a number of foci of a sufficient number of vapour molecules to form bubbles large enough to withstand the consequent compression due to surface tension. These bubbles will then act as centres of evaporation, growing with great rapidity.

Discharges through nozzles four or five times those calculated from the thermodynamic theory are thus due to the delay in vaporisation of the air-free water, allowing a greater pressure drop without evaporation until the throat is reached. The velocity, U, of the water in the throat before vaporisation commences is given by the formula

$$U^2 = 2\,gV_w\,(P_1 - P_w) = 2\,gh \text{ in ft.-lb. sec. units}, \quad (3)$$

where g is the acceleration due to gravity, V_w is the specific volume of the water, P_1 is the saturation pressure corresponding to the initial temperature of the water, P_w is the hydrostatic pressure of the water at which vaporisation actually commences, and h is the static equivalent to the differences between the saturation pressure and the pressure at which vaporisation actually commences.

Discharges lower than these maxima and down to the lower limit, as calculated in Appendix I, are controlled by steam bubbles entering the nozzle with the boiling water and serving as centres of evaporation as expansion in the nozzles proceeds. In the case of sharp-edged orifices, the air-free water passes the orifice before any vaporisation occurs.

The main point of interest, as shown by Fig. 2, is that nozzles are capable of dealing with a variation in flow of at least four or five to one with the same initial pressure without flooding, and without passing any appreciable amount of initial steam; and, therefore, they should be perfectly satisfactory substitutes for ball-float traps. The trap controls the flow by varying the throat area, while the nozzle controls the flow by varying the throat pressure.

For an orifice, under a static head of h ft., equation (1) becomes

$$\frac{M}{X} = 0{\cdot}6\,\rho\sqrt{2g\left(\frac{P_1 - P_2}{\rho} + h\right)}. \quad . \quad (1a)$$

For a nozzle, equation (5), on the opposite page, becomes

$$\frac{M}{X} = \rho\sqrt{2g\left(\frac{cP_1}{\rho} + h\right)} \quad . \quad . \quad (5a)$$

c being a coefficient.

When the initial temperature is below the temperature of saturation, the discharge of an orifice will still depend on the pressure difference only. The discharge of a nozzle will be increased, and equation (5) becomes

$$\frac{M}{X} = \sqrt{2g\,\rho\,(cP_1 + P_1 - P_2)} \quad . \quad . \quad (5b)$$

---

* Reprinted from the *Journal of the Institution of Engineers Australia*, vol. 18. Abridged.

† *Annales des Mines* (1902).

‡ *Trans. N.E.C. Inst.*, vol. 53, page 65 (1936–7).

§ "The Flow of Saturated Water Through Throttling Orifices," by M. W. Benjamin and J. G. Miller. *Trans. A.S.M.E.*, July, 1944.

FLOW OF BOILING WATER.

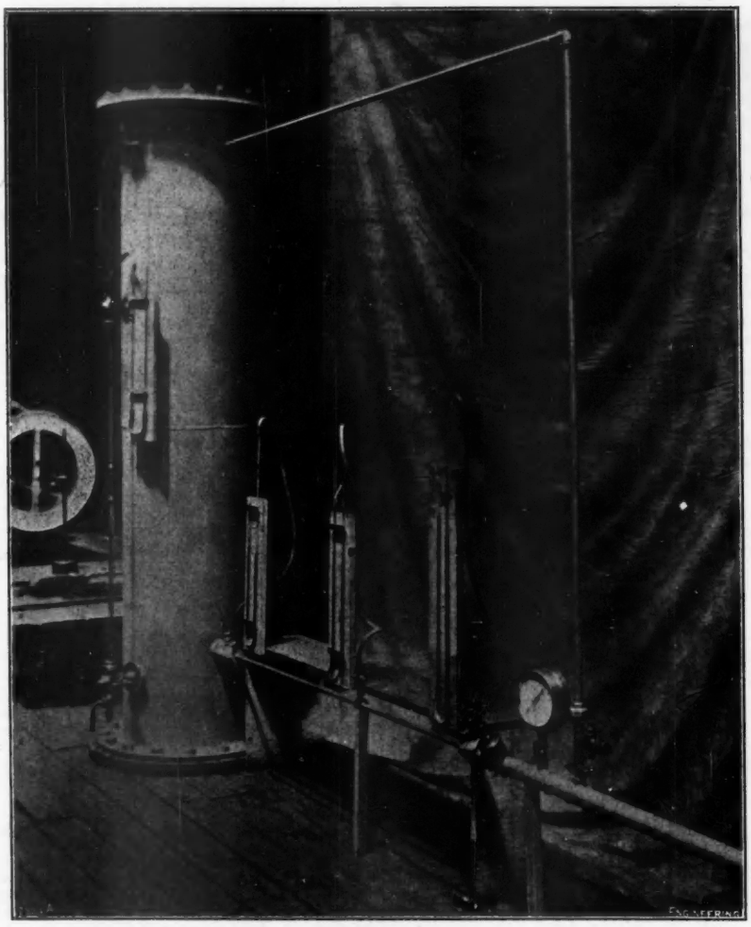


FIG. 1.

TABLE I.

Pressure.	Temp. deg. C.	σ	$c = \frac{0{\cdot}264\,\sigma}{49{\cdot}2}$	$\frac{cP}{\rho} = \frac{U^2}{2g}$	U.	ρ	$\frac{M}{X}$
5	72·5	65·4	0·350	4·14	16·3	61·0	995
10	89·5	63·1	0·3385	8·09	22·8	60·2	1,370
15	100·5	61·5	0·330	11·9	27·6	59·8	1,650
20	109·0	60·25	0·323	15·65	31·8	59·5	1,890
30	121·0	58·6	0·3145	23·1	38·5	58·8	2,270
40	131·0	57·2	0·307	30·3	44·1	58·4	2,580
60	145·0	55·1	0·296	44·5	53·5	57·4	3,070
80	156·0	53·7	0·288	58·5	61·5	56·8	3,485
100	164·0	52·5	0·282	71·8	67·7	56·5	3,830
120	172·0	50·6	0·272	98·8	79·9	55·5	4,430
140	178·0	50·6	0·272	98·8	79·9	55·5	4,430
160	184·0	49·8	0·267	112·0	84·8	55·0	4,660
175	188·0	49·2	0·264	122·0	88·4	54·6	4,830

where P_1 is the initial pressure, in lb. per square foot, P_2 is vaporisation pressure for initial temperature, and ρ is density of water at initial temperature.

It will be seen that the increased discharge, due to static head on the nozzle and undercooling of the condensate, tend further to increase the discharge capacity of a nozzle. This further increases the range of self-regulation of the nozzle where it is used to remove condensate from a tubular heater, because any flooding of the tubes will increase the head and at the same time undercool the condensate. In the experiments carried out by the author, the nozzle was flooded in all cases; the discharges plotted are those corresponding to $h = 0$ and are the maximum for such condition.

Now, calculating from the measured discharges and putting

$$\frac{M}{X}\text{ (lb.-ft. sec.)} = \sqrt{2\,gc\,P_1\rho_1} \quad . \quad . \quad (5)$$

where X = area of nozzle throat, in square feet, P_1 = initial pressure, in lb. per square foot, ρ_1 = initial density in lb. per cubic foot, and c = a coefficient, it is found that the throat velocity corresponds to a pressure drop of about $0{\cdot}3\ P_1$ ($0{\cdot}35\ P_1$ at 5 lb. per square inch, and $0{\cdot}264\ P_1$ at 175 lb. per square inch). The critical pressure drop corresponds, therefore, to a nearly constant ratio of expansion, which implies a nearly constant temperature drop. The equation

$$P_v - P_w = \frac{2\sigma}{r}$$

may be written

$$c\,P_1 = \frac{2\sigma}{r} \text{ or } c = \frac{2\sigma}{P_1 r}. \quad . \quad . (6)$$

The experimental results suggest that $P_1 r$ may be constant and that variations in c correspond to variations in σ. Table I, therefore, has been computed on this assumption.

Taking the experimental value of $\frac{M}{X} = 4{,}830$ for 175 lb. per square inch absolute, the corresponding velocity in throat $= \frac{M}{X}\frac{1}{\rho} = \frac{4{,}830}{54{\cdot}6} = 88{\cdot}4$ ft. per second; then

$$\frac{U^2}{2g} = \frac{88{\cdot}4^2}{64{\cdot}3} = 122 \text{ ft.},$$

and

$$\frac{h\rho}{P} = \frac{122 \times 54{\cdot}6}{175 \times 144} = 0{\cdot}264,$$

which is the value of c for 175 lb. per square inch. It is then assumed that, for any other pressure,

$$c = \frac{0{\cdot}264 \times \sigma \text{ for corresponding saturation pressure}}{\sigma \text{ for 175 lb. saturation}},$$

$$= 49{\cdot}2$$

For water freed from dissolved air and gases, Hall found

$$\sigma = 75{\cdot}48 - 0{\cdot}14\,t\,(\text{deg. C.}) \quad . \quad . \quad (7)$$

The upper curve of Fig. 2 represents the results obtained in Table I, and it will be seen that it is in very close agreement with the experimental points determined by Bottomley and the author. It is also very similar to an experimental curve given by D. R. Yarnall in the discussion on the paper by Benjamin and Miller.

For the radius r, of the bubbles of critical size at 15 lb. per square inch absolute, we have (using c.g.s. units)

$$r = \frac{2\sigma}{\rho g h} = \frac{2 \times 61{\cdot}5}{0{\cdot}96 \times 981 \times 363} = 3{\cdot}6 \times 10^{-4} \text{ cm.};$$

and, for 150 lb. per square inch,

$$= 3{\cdot}6 \times 10^{-4} \times \frac{15}{150} = 3{\cdot}6 \times 01^{-5} \text{ cm.},$$

since Pr has been shown to be constant. This constancy of Pr and the determination of the size of the bubbles may prove of value in connection with the theory of cavitation. The same principle has been used to explain the supersaturated state of steam flowing through a nozzle, but in this case it is applied to drops of water surrounded by dry steam, and the signs are reversed.

It has been shown by Callendar,* Martin,† and Binnie‡ that the supersaturation of rapidly expanding steam continues until condensation finally takes place on nuclei of a radius of about 5×10^{-8} cm. Over the range of Binnie's experiments, the value of Sr is constant, S being the ratio at the limit of supersaturation of

$$\frac{\text{Actual pressure}}{\text{Satn. pres. for temp. of the steam}}.$$

The radius of a molecule of water vapour is given by Jeans as $2{\cdot}29 \times 10^{-8}$ cm.; hence it is inferred that, in the case of supersaturated steam, when condensation occurs, it takes place on the co-aggregated molecules as nuclei. These are paired molecules, the effect of which on the diminution of the specific volume of steam is expressed by the term C in Callendar's equation of state:—

$$V - b = \frac{RT}{aP} - c.$$

It is seen, then, that the bubbles controlling the limit of superheating in boiling water are many times larger than the nuclei limiting the supersaturation of steam.

When saturated water flows in a pipe of uniform cross section, the discharge, $\frac{M}{X}$ (lb. per second per square foot), will be constant throughout its length, while the velocity at any point will be determined by the specific volume at that point. The energy liberated by the fluid expanding adiabatically will be expended partly in pipe friction and partly in increased kinetic energy. Bottomley§ shows that, when saturated water is discharging through a pipe of economical diameter to a receiver, the discharge will depend, in general, on the initial pressure and not on the receiver back pressure, and there will be a critical pressure at the outlet of the pipe greater than that in the receiver.

Considering the changes that take place between two adjacent cross sections of the pipe near the outlet under critical pressure conditions: as the pressure falls, the volume, V, will increase, and so will the kinetic energy and the work available, in accordance with the equation

$$-V\,dP = \frac{2}{2g}\,U\,dU + J\,dQ$$

$$-\left(\frac{M}{X}\right)^2 \frac{2}{2g}\,V\,dV + J\,dQ;$$

J being, of course, the mechanical equivalent of heat, and Q, the quantity of heat supplied per unit mass, in B.Th.U.

The critical pressure is reached when the increase in work available balances the increase in kinetic energy, there being then no energy available for overcoming pipe friction. Putting, then, $d\,Q = 0$, we obtain

$$\left(\frac{M}{X}\right)^2 = -g\left(\frac{dP}{dV}\right)\phi.$$

* *Properties of Steam*, by H. L. Callendar.

† "A New Theory of the Steam Turbine," by H. M. Martin. ENGINEERING, vol. 106, pages 1, *et seq.* (1918).

‡ "Pressure Distribution in a Convergent-Divergent Steam Nozzle," by A. M. Binnie and M. W. Woods. *Proc. I Mech E.*, vol. 138, page 229 (1938).

§ *Loc. cit.*

FLOW OF BOILING WATER THROUGH NOZZLES.

Fig. 2.

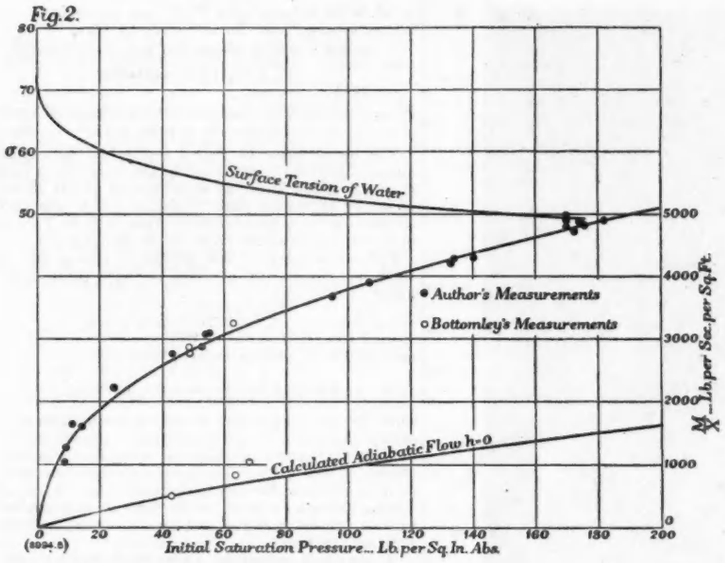
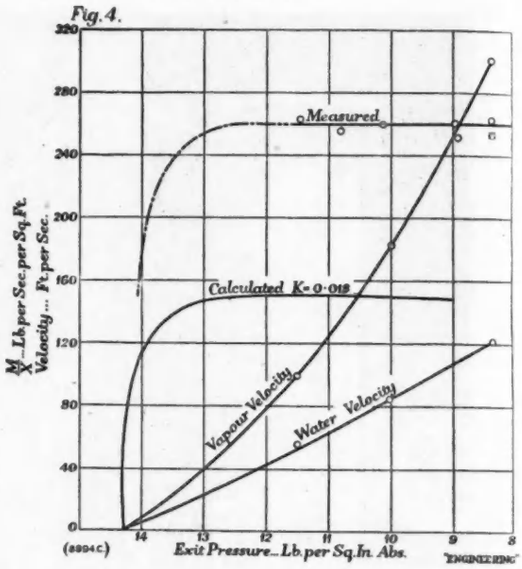

Surface Tension of Water
• Author's Measurements
○ Bottomley's Measurements
Calculated Adiabatic Flow h=0
Initial Saturation Pressure... Lb. per Sq. In. Abs.
M/X ... Lb. per Sec. per Sq. Ft.
(8994.B)

Fig. 4.



This is the same general equation which Callendar* gives for the critical discharge at the throat of a nozzle, and it follows therefrom that the exit velocity from the pipe is equal to the local velocity of sound in the mixture of vapour and water.

Bottomley measured the flow and pressures in a 100-ft. length of pipe following a nozzle; before the nozzle, the saturated water was at 41 lb. pressure, and, following the nozzle, at 37·5 lb.; the pressure at exit was 22 lb., and in the receiver 16 lb. absolute. The flow as measured was $\frac{M}{X} = 260$ lb. per second per square foot, and the calculated coefficient of pipe friction was K = 0·012 in.; the equation

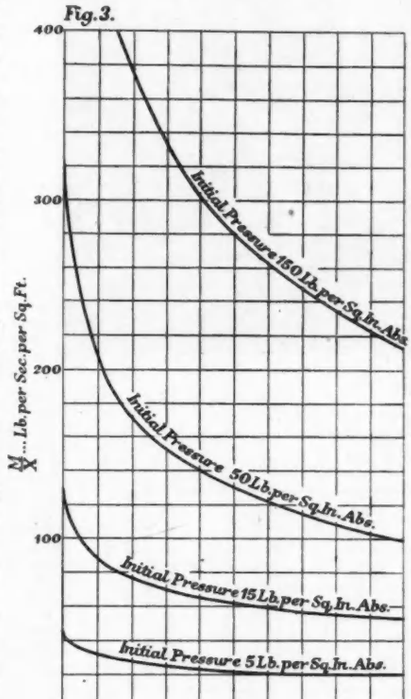
$$J\,dQ = \frac{U^2}{2g}\,\frac{K\,dl}{D}.$$

Benjamin and Miller† carried out somewhat similar measurements of the flow of saturated water through pipes following a nozzle or orifice, and obtained results agreeing reasonably with Bottomley's experiments and confirming a mean value for K = 0·012. Instead of measuring pressures, they placed thermo-couples at various points along the piping and assumed the pressures to be those corresponding to the saturation temperatures observed. Fig. 3, herewith, shows discharge rates of pipes following an orifice or nozzle, computed by Bottomley for the assumptions there stated and using K = 0·012. In this figure, l = length of pipe in feet, M = total flow in lb. per second, and X = sectional area of pipe in sq. ft.

Using the equipment described in the first part of the paper and illustrated in Fig. 1, the author made numerous measurements of the flow of boiling water through pipes, both with and without a preceding nozzle. Some of the results obtained are given in Tables II and III, opposite. Except for high pressures and relatively long pipes, it will be seen that the measured discharges are from 1½ to twice the calculated discharges, while the pressures at exit from the pipes are considerably below the calculated critical exit pressures. In the experiments of both Bottomley, and Benjamin and Miller, the actual discharges and exit pressures corresponded fairly closely with those calculated from thermodynamic data. The discrepancy therefore calls for investigation.

Unduly high discharges would have resulted in the author's experiments if the water had been initially below boiling temperature, but thermometer readings, lively ebullition and escape of surplus steam all indicated that the water in the vessel was actively boiling. At one time, a copper heating coil placed at the bottom of the hot-water vessel was substituted for under-water direct-injection heating, but without any difference in results. All pressures or vacua up to 30 in. Hg were read on mercury manometers, and thermometers were calibrated. In carrying out the higher pressure tests with water drawn from the drum of a water-tube boiler, the boiler feed pump was stopped after the water

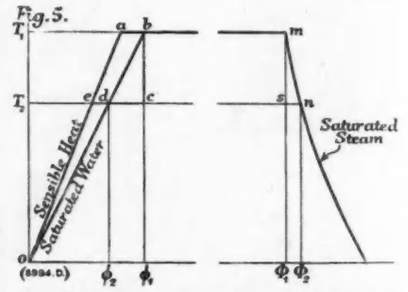
Fig. 3.


Initial Pressure 150 Lb. per Sq. In. Abs.
Initial Pressure 50 Lb. per Sq. In. Abs.
Initial Pressure 15 Lb. per Sq. In. Abs.
Initial Pressure 5 Lb. per Sq. In. Abs.
M/X ... Lb. per Sec. per Sq. Ft.
l/√M
(8994.E)

showed a full glass, a small amount of evaporation was allowed to occur, and the pressure then allowed to drop by about 20 lb. before starting the test, to ensure that the water was at a temperature corresponding to saturation. Increased discharge would obtain, also, if there were a lag in the flashing of the water into steam, just as occurs in a short nozzle. This would result in the water in the pipe being superheated; that is, at a temperature above the boiling point temperature for its pressure.

A mercury-in-glass thermometer was inserted in the pipe through a gland near the exit, with the bulb projecting very slightly into the pipe and opposite to a tapping for a mercury manometer. Placed at the top of the pipe, the thermomenter gave readings agreeing exactly with the saturation temperature for the corresponding pressure. This was naturally so, as the bulb was in a small pocket of vapour. Turning the tube 180 deg. brought the thermometer to the bottom of the tube, but it still read a temperature corresponding with

Fig. 5.



the normal boiling point for the pressure. Later a thermocouple was fitted in place of the glass thermometer, but little, if any, superheating of the water could be detected. A slight increase of discharge, particularly in the case of the smallest size of pipe, might be attributable to heat losses, causing a reduction of specific volume. The pipe was, therefore, well lagged, but the consequent reduction in discharge was only of the order of 1 per cent. to 3 per cent.

If there is no sensible loss of heat during flow and no lag in the flashing of the water, the energy liberated by fall of pressure in the pipes will be that due to adiabatic expansion (the re-heating effect being negligible), and this work must be absorbed in overcoming pipe friction and in the increased kinetic energy of the fluid at exit. An example will make this clear.

Boiling water, at an initial pressure of 14·30 lb. per square inch absolute, flows through 24 ft. of brass tube of 0·904 in. internal diameter. Calculation of the flow, using K = 0·018, gives a maximum flow of $\frac{M}{X} = 152$ lb. per second per square foot and a critical pressure at exit of 11·50 lb. per square inch, the density of the mixture at this pressure being 2·636 lb. per cubic foot. The fall in temperature, dt, is from 210·6 deg. to 199·9 deg. = 10·7 deg. F.

By the entropy-temperature diagram, adiabatic drop—

$$dh\phi = (0{\cdot}3097 - 0{\cdot}2936)\,\frac{10{\cdot}7}{2} + \frac{0{\cdot}0166 \times 980 \times 10{\cdot}7}{33{\cdot}72 \times 662}$$

$$= 0{\cdot}0861 + 0{\cdot}0093 = 0{\cdot}0954 \text{ B.Th.U. per lb.}$$

$$= 74{\cdot}2 \text{ ft.-lb. per lb.}$$

The second term in the above equation relates to the vapour in solution in the liquid. Now,

$$\frac{M}{X} = \frac{U}{V},$$

therefore U at exit $= \frac{152}{2{\cdot}636} = 57{\cdot}6$ ft. per second and $\frac{57{\cdot}6^2}{2g} = 51{\cdot}7$ ft.-lb. per lb. kinetic energy and 74·2 − 51·7 = 22·5 ft.-lb. per lb. loss in friction; but measured discharge was actually $\frac{M}{X} = 260$ lb. per second per square foot, with an exit pressure of 11·50 lb. per

* *Loc. cit.*

† "The Flow of a Flashing Mixture of Water and Steam Through Pipes," by M. W. Benjamin and J. G. Miller. *Trans. A.S.M.E.*, October, 1942.

square inch. This means a combined friction loss and exit kinetic energy

$$= 74{\cdot}2 \times \left(\frac{260}{152}\right)^2 = 217 \text{ ft.-lb. per lb.}$$

where only 74·2 ft.-lb. per lb. are available. A similar discrepancy between the measured and calculated flow occurs in all the author's experiments.

This was very puzzling until it was realised that, in the method for computing the discharge, it had been tacitly assumed that the steam and liquid particles in any cross section of the pipe both moved with the same velocity. Both Bottomley, and Benjamin and Miller, make this assumption. It must be very nearly correct in the case of steam flowing through a nozzle, where the mass of the liquid particles is only some 5 per cent. of the whole and is in an extremely finely divided state. In a flashing mixture of water and steam, however, the water is not nearly so finely divided and some 95 per cent. by mass has to be accelerated by the bombardment of only 5 per cent. of steam. Under these conditions, it is very improbable that the water particles travel as fast as the steam particles. Further, it would be expected that the greater discrepancy between the velocities of the steam and water would occur with low pressures and short pipes, and the minimum discrepancies with high pressures and long pipes, and experiments support this conclusion.

Assuming that the steam travels at one velocity and the water at another, the velocities of the two states can be readily calculated in the above example, using the suffix v to indicate vapour and the suffix w, water. Weight of flash formed per lb. (from entropy-temperature diagram)

$$= \frac{\phi_1 - \phi_2}{\Phi_2 - \phi_2} = \frac{0{\cdot}0161}{1{\cdot}7765 - 0{\cdot}2936} = 0{\cdot}01085 \text{ lb.};$$

and, assuming pipe-friction loss = 22·5 ft.-lb. per lb., as before, we have

$$0{\cdot}01085 \frac{U_v^2}{2g} + 0{\cdot}99 \frac{U_w^2}{2g} = 51{\cdot}7 \text{ ft.-lb. per lb.}$$

For each pound of mixture:
volume of vapour = 33·72 × 0·01085 = 0·366; and
volume of water = 0·0166 × 0·99 = 0·0164.

Assume the velocity of water is $\frac{1}{1{\cdot}75}$ of the steam velocity (as found by approximate first trial), the portion of the cross section of the pipe filled by water flow will be 1·75 times that for equal velocities. Then, specific volume of vapour × lb. per second = vapour velocity × area of flow.

$$33{\cdot}72 \times (0{\cdot}01085 \times 260) = \text{vapour velocity} \times \frac{0{\cdot}366}{0{\cdot}366 + (0{\cdot}0164 \times 1{\cdot}75)}.$$

$$\text{Vapour velocity} = 95 \times \frac{0{\cdot}395}{0{\cdot}366} = 102{\cdot}7 \text{ ft. sec.};$$

therefore, kinetic energy of vapour

$$= 0{\cdot}01085 \times \frac{102{\cdot}7^2}{2g} = 1{\cdot}76 \text{ ft.-lb. per lb.}$$

Then,

$$0{\cdot}99 \frac{U_w^2}{2g} = 51{\cdot}7 - 1{\cdot}76 = 50 \text{ ft.-lb. per lb.}$$

$$U_w = 57 \text{ ft. per sec.}$$

The ratio $\frac{\text{vapour velocity}}{\text{water velocity}}$ is 1·8; so the assumption above is close enough. Another measurement with the same pipe gave $p_1 = 14{\cdot}30$ lb., $p_{exit} = 8{\cdot}35$ lb. absolute, and $\frac{M}{X} = 260$. This gives a dryness fraction of 2·48 per cent. at exit, with a steam velocity of 302 ft. per second and a water velocity of 123 ft. per second, the velocity ratio being 2·4 to 1.

Taking an example with a longer pipe and higher pressures, 76 ft. of 1¼-in. pipe following a nozzle 0·364 in. in diameter, with $p_1 = 116$ lb. per square inch., gave p, following the nozzle, as 65·4 lb. per square inch, p_{exit} as 14·7 lb., and $\frac{M}{X} = 227$.

TABLE II.—FLOW OF BOILING WATER IN PIPES.

p_1.	$\frac{M}{X}$ Calculated.	$\frac{M}{X}$ Measured.	$\frac{M}{X}$ Measured. / Calculated.	p_{exit} Calculated.	p_{exit} Measured.
5 ft. of 0·529 in. int. dia. brass tube.					
24	266	410	1·54	20·75	14·8
14·3	183	353	1·92	12·5	10·2
8·82	118	190	1·61	7·5	5·1
20 ft. of 0·529 in. int. dia. brass tube.					
14·3	139	225	1·62	10·0	7·0
20 ft. of 0·904 in. int. dia. brass tube.					
14·3	158	313	1·98	11·25	8·69
45 ft. of 0·904 in. int. dia. brass tube (equiv. length).					
14·3	129	175	1·36	10·0	6·2
82 ft. of 1¼ in. int. dia. mild-steel pipe (straight).					
114	585	595	1·02	60·0	44·5
158	740	715	0·965	75·0	58·5
52·4	343	500	1·46	30·0	25·4
44 ft. of 1¼ in. int. dia. mild-steel pipe (straight).					
54·4	413	820	1·98	36·0	37·4

TABLE III.—FLOW OF BOILING WATER IN PIPES FOLLOWING AN ORIFICE OR NOZZLE.

p_1.	p_2.	$\frac{M}{X}$ Calculated.	$\frac{M}{X}$ Measured.	$\frac{M}{X}$ Measured. / Calculated.	p_{exit} Calculated.	p_{exit} Measured.
5 ft. of 0·529 in. int. dia. brass tube following 0·213 in. nozzle.						
24	18·67	152·5	234	1·54	12·5	9·85
14·12	11·24	99·0	189	2·0	7·2	6·3
8·2	6·35	58·8	115	1·96	4·16	3·43
20 ft. of 0·529 in. int. dia. brass tube following 0·213 in. nozzle.						
14·12	12·5	85·0	138	1·62	6·0	5·0
20 ft. of 0·904 in. int. dia. brass tube following a nozzle 0·364 in. dia.						
14·3	12·0	91·0	172	1·89	7·0	5·9
20 ft. of 0·904 in. int. dia. brass tube following a nozzle 0·2815 in. dia.						
14·3	10·0	64·7	112	1·73	5·8	4·2
20 ft. of 0·904 in. int. dia. brass tube following a nozzle 0·213 in. dia.						
14·3	8·0	45·0	72·0	1·6	3·9	2·96
76 ft. of 1¼ in. int. dia. mild-steel tube following nozzle 0·364 in. dia.						
115·9	65·4	208·0	227·0	1·09	26·0	15·0
38 ft. of 1¼ in. int. dia. mild-steel pipe following nozzle 0·364 in. dia.						
115·9	53·4	205·0	245·0	1·19	28·0	17·0

By calculation, assuming water and steam velocities identical, $\frac{M}{X} = 208$, $p_{exit} = 24$ lb., and common velocity at exit = 361 ft. per second. For measured flow, the dryness fraction at outlet is 12·3 per cent., the vapour velocity 745 ft. per second, and the water velocity 497 ft. per second, a velocity ratio of 1·5 to 1.

Fig. 4, opposite, shows the calculated and measured discharges through 24 ft. of 0·904 in. internal diameter brass tube for saturated water at an initial pressure of 14·3 lb. per square inch. It will be seen that, while the calculated value of $\frac{M}{X}$ reaches a maximum value of 152 at an exit pressure of 11·5 lb. per square inch., the computed flow falls very slowly with decreasing pressure and has a value of 148, even at 9 lb. per square inch. This suggested that the actual discharge may remain sensibly constant, while the exit pressure varies considerably. A series of measurements was therefore made with constant inlet pressure and temperature, but with the back pressure successively raised from below the minimum exit pressure up to an exit pressure corresponding to that calculated for maximum flow. The results are given in Table IV and are plotted in Fig. 4. The discharge is sensibly constant over the range of exit pressure used. The velocities of the steam and water calculated from the measured flows are also shown plotted in Fig. 4.

TABLE IV.—*Flow of Boiling Water Through 24 Ft. of 0·904 In. Brass Tube.*

p_{inlet}.	p_{exit}.	$\frac{M}{X}$ measured, lb. per sec. per sq. ft.
14·30 lb. per sq. in.	8·35 lb. per sq. in.	264
	8·35 " "	254
	8·90 " "	252
	8·95 " "	261
	10·1 " "	260
	10·80 " "	256
	11·45 " "	264

In spite of the fact that the velocity of the water lags considerably behind that of the steam, the discharge through a given pipe system has a critical value depending on the initial saturation pressure, but is insensitive to the back pressure or to the exit pressure within considerable limits. Over this range of exit pressures, we may write—

$$\frac{M}{X} = \frac{U_{vapour}}{V_{vapour}} = \frac{dU_{vapour}}{dV_{vapour}} = \text{constant},$$

neglecting the small volume occupied by the water particles.

In all the author's calculated values for the flow in pipes, a value of K = 0·018 has been used for the coefficient of friction in the formula

$$h = K \frac{U^2}{2g} \frac{dl}{D}.$$

This is the approximate mean value of K for the Reynolds numbers corresponding to the range of velocities and temperatures of both steam and water used in the experiments (D is the pipe diameter in feet). The discharges calculated by Bottomley, and by Benjamin and Miller, using K = 0·012, are approximately 15 per cent. higher than if 0·018 is used. When correction is made for this, it is again only possible to explain the greater measured discharges by assuming that the water velocity is less than that of the steam in the mixture. Their results then come into much better agreement with the author's. The fact, proved by the author's experiments, that the steam and the water move at different velocities in a tube, is of importance in various applications; for example, in connection with the circulation induced in water-tube boilers and evaporators.

Generally, when a steam trap or nozzle is fitted in a drain line, it is desirable to locate the trap below the level of the take-off point of the drain, so that no flashing will occur before the trap or nozzle is reached. The drain pipe leading to the trap or nozzle can then be designed as for cold-water flow. The pipe leading the flashing mixture from the trap or nozzle to the point of discharge should be as short and direct as possible and must be of increased size—very considerably increased size where the discharge pressure is much below atmospheric.

In fixing sizes for such a system, it is good practice to make the size of the nozzle so that it will be capable of passing twice the normal flow. Besides the overload capacity thus provided, it will then be capable of operating down to at least half the normal flow without passing any appreciable quantity of steam. The size of pipe to be adopted following the nozzle may be calculated, but can generally be determined by using Bottomley's curves, reproduced in Fig. 3. Calculated results can then be modified in the light of the experimental results set out in Tables II and III. Sizes fixed

from Bottomley's curves will be over-large for initial pressures of atmospheric and below, whereas some slight margin should be allowed for pressures above 50 lb. per square inch and lengths over, say, 40 ft.

APPENDIX I.—CALCULATION OF THE FLOW OF BOILING WATER THROUGH A NOZZLE.

The equations for the flow of boiling water through a nozzle are most readily derived from the entropy-temperature diagram. For this purpose, the diagram must be drawn to a more open scale of entropy on the water side. There are really two water lines, indistinguishable from one another as usually drawn. The one to the left, $o\,e\,a$ (Fig. 5, page 574), is the usual logarithmic line representing the specific heat of water of nearly unity, and the other, $o\,d\,b$, is the saturated water line, which allows for the fact, discovered by Callendar, that water at saturation temperature contains its own volume of vapour in solution, which contributes the term $\frac{V_w L}{V_s - V_w}$ to the total heat h of the liquid; L is the latent heat of saturated steam, in B.ThU. per pound.

In Fig. 5, the adiabatic heat drop from P_1 and T_1 to P_2 and T_2 is measured by the area $a\,b\,c\,d\,e$, and this energy, assuming the frictional resistance of the nozzle negligible, will take the form of kinetic energy at exit from the nozzle. The adiabatic drop is

$$dh\phi = (T_1 - T_2)\phi_1 - (G_1 - G_2) \quad . \quad . \quad (8)$$

where G is Gibbs potential as given in Callendar's tables; but the heat drops for boiling water in nozzles are too small to be determined by differences between large quantities and can best be calculated directly from the ϕT diagram as follows:—

$$ab \text{ and } ed = \frac{LV_w}{V_s - V_w}\frac{1}{T}; \text{ take the mean value,}$$

then area

$$abde = \frac{LV_w}{V_s - V_w}\,\frac{T_1 - T_2}{T}$$

and area

$$bcd = \frac{\phi_1 - \phi_2}{2}(T_1 - T_2)$$

therefore

$$dh\phi = \frac{\phi_1 - \phi_2}{2}(T_1 - T_2) + \frac{LV_w}{V_s - V_w}\,\frac{T_1 - T_2}{T} \quad . \quad . \quad . \quad (9)$$

The exit velocity will then be

$$U = 224\sqrt{dh\phi} \quad . \quad . \quad . \quad (10)$$

Also, from Fig. 5, the specific volume at T_2 is obviously

$$V = V_w + \frac{(\phi_1 - \phi_2)(V_s - V_w)}{\Phi_2 - \phi_2} \quad . \quad (11)$$

and the flow $\frac{M}{X}$ lb. per second per square foot $= \frac{U}{V}$.

Take, as an example, the flow of saturated water from an initial pressure of 100 lb. per square inch to an exit pressure of 90 lb. per square inch.

$$t_1 = 327{\cdot}9 \text{ deg. F.}, \; t_2 = 320{\cdot}2 \text{ deg. F.},$$

$$T_1 - T_2 = 7{\cdot}7 \text{ deg. F.}$$

$$V_{exit} = 0{\cdot}0176 + \frac{(4{\cdot}891 - 0{\cdot}017)(0{\cdot}4749 - 0{\cdot}4646)}{1{\cdot}6161 - 0{\cdot}4646}$$

$$= 0{\cdot}0612.$$

$$dh\phi = \frac{0{\cdot}0103 \times 7{\cdot}7}{2} + \frac{0{\cdot}0350 + 0{\cdot}0320}{2}$$

$$= 0{\cdot}0397 + 0{\cdot}0335$$

$$= 0{\cdot}0732 \text{ B.Th.U.}$$

Exit velocity $= 224\sqrt{0{\cdot}0732} = 60{\cdot}8$ ft. per second, and

$$\frac{M}{X} = \frac{U}{V} = \frac{60{\cdot}8}{0{\cdot}0612} = 993 \text{ lb. per second per square foot.}$$

Calculated values of $\frac{M}{X}$ for exit pressures of 92 lb. and 88 lb. per square inch, are 985 and 989, respectively; therefore, the calculated actual discharge will be that corresponding to maximum flow, that is, 993 lb. per square foot per second, with an exit pressure of approximately 90 lb. per square inch—a much smaller critical drop than would occur with steam flowing through the nozzle from the same initial pressure. In his work, Rateau omitted the latent heat term in his values of $dh\,\phi$. In the example above, this would nearly halve the available energy, showing why he found difficulty in understanding some of his results.

INSTITUTION OF NAVAL ARCHITECTS.—The next annual general meeting of the Institution of Naval Architects will commence on Wednesday, March 17, 1948.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

ABSTRACTS OF SPECIFICATIONS RECENTLY PUBLISHED UNDER THE ACTS OF 1907 TO 1939.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned, the Specification is not illustrated.

Where inventions are communicated from abroad, the Names, etc., of the Communicators are given in italics.

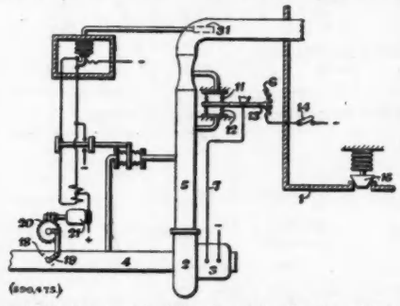
Copies of Specifications may be obtained at the Patent Office Sales Branch, 25, Southampton Buildings, Chancery-lane, London, W.C.2, price 1s. each.

The date of the advertisement of the acceptance of a Complete Specification is given after the abstract in each case, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Acts.

AERONAUTICS.

590,475. Pressurisation of Aircraft Cabins. The British Thomson-Houston Company, Limited, of London. (1 *Fig.*) August 24, 1944.—This invention relates to apparatus for regulating the supply of air from a compressor to an aircraft cabin and also regulating the temperature of the air. The apparatus is responsive to the amount of air delivered by the compressor to the enclosure for regulating the speed of the compressor, controlling the flow of air through the compressor, and maintaining the correct air temperature. The cabin of an aircraft which it is desired to supercharge is indicated at 1. Connected with the cabin is a centrifugal compressor 2 which is driven by an electric motor 3. Air is supplied to compressor 2 through a conduit 4 and is discharged from the compressor through a conduit 5 to the cabin. The speed of the supercharger is controlled by a rheostat 6 in the motor circuit 7. The rheostat 6 is operated by opposed bellows 11 and 12 having their movable ends

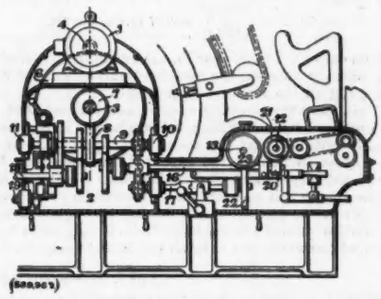


(590,475)

pivoted to the arm 13 of the rheostat. In the cabin is a hand switch 14 for opening and closing the motor circuit. A valve 15 is provided in the wall of the cabin to maintain a constant pressure therein. In the inlet conduit 4 is located a throttling valve 18 having an actuating arm 19 connected through gearing 20 to a reversing electric motor 21. The direction of rotation of the motor is controlled by contacts which reverse the motor field, these contacts being actuated by a thermostatic device 31 in the conduit 5. If the temperature of the air flowing through conduit 5 increases, motor 21 rotates in a direction to open valve 18, thus decreasing the throttling of the air supplied to the compressor and so decreasing the temperature of the air. In a similar manner, if the temperature of the air flowing through conduit 5 decreases, the motor rotates in a direction to close valve 18, thus increasing the throttling of the air supplied to the compressor and thereby increasing the temperature of the air. (*Accepted July* 18, 1947.)

TEXTILE MACHINERY.

589,969. Driving of Carding Engines. Tweedales and Smalley (1920), Limited, of Castleton, Lancaster, and E. G. Smalley, of Castleton. (3 *Figs.*) January 3, 1945.—According to this invention the main drive to the carding engine is transmitted by a motor to a gearbox from which various parts of the carding engine can be positively driven at selected speeds by gear wheels, shafts and chains, the driving of the doffer comb being effected by a separate direct-coupled motor arranged to synchronise with the main driving motor. The whole of the driving mechanism is confined to one side of the carding engine, and all parts are encased where necessary. An electric motor 1 is mounted on a centrally disposed gearbox 2 in a position that is vertically above the main cylinder shaft 3, a pinion 4 being fixed on the motor shaft to drive a toothed wheel 6 on the main cylinder shaft 3. Fixed on the latter is a helical gear 7 that meshes with a gear 8 on a countershaft 9 mounted in ball bearings 10 and 11 in the gearbox 2. From shaft 9 the four main rotary units are driven by means of four shafts 16, 17, 18 and 19, extending through the gearbox 2 to each respective unit. The feed roller 12 is driven by a worm 20 and worm-wheel 21. The licker in roller 13 is driven by the helical gears 22 and 23. The doffer and the coiler delivery box are also driven by means of helical gears. Provision is

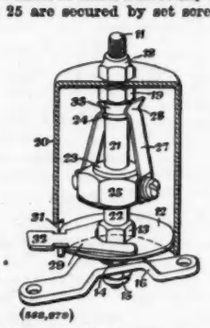


(589,969)

made in the gearbox 2 for change wheels, whereby the speed at which each of the four units can be driven can be changed according to the production of the card. (*Sealed.*)

MISCELLANEOUS.

588,879. Shock Indicator. P. H. Watson, of South Farnborough, Hampshire. (2 *Figs.*) March 8, 1945.—This invention relates to a shock-indicating device suitable for attachment to a structural member of an aircraft or vehicle to indicate the magnitude of a shock to which the member has been subjected. The instrument is of the accelerometer type having one degree of freedom, for linear acceleration in the vertical direction only, and it has two possible indications, corresponding to whether the acceleration in the vertical direction to which the instrument has been subjected has or has not exceeded an assigned critical magnitude. The indicator comprises a central vertical bolt 11 threaded at both ends, to which a base plate 12 is secured by nuts 13, 14, while a further nut 15 secures the bolt 11 to a mounting bracket 16 for attaching the indicator to a convenient support in an upright position. The upper end of bolt 11 carries nuts 18, 19, between which is secured a transparent cover 20 in the form of a cylinder with a closed upper end, the latter being centrally pierced to accommodate the bolt 11. The bolt 11 carries sleeves 21, 22, 33, separated by a stop washer 23, and washer 24, the assembly of sleeves and washers being located and gripped between the nuts 13, 19. The assembly 11, 21, 22, 33, constitutes the stem on which a mass 25 is mounted, the mass being perforated centrally so that it can slide on the sleeve 22 between the washer 23 and the nut 13. The washer 24 forms a smoothly rounded collar. To the mass 25 are secured by set screws two spring



(588,879)

tongues 27 which are inclined upwards and inwards and the free ends of which are joggled to provide smoothly rounded projections, 28, which engage over the collar 24 and thereby suspend the mass in the position shown. A forked resetting lever 29 is provided, which rocks on a fulcrum consisting of an upturned portion of the rim of the base of the plate 12. This lever projects through a cut-out portion 31 of the transparent cover 20 and terminates in a finger plate 32, enabling the lever 29 to be manipulated for raising the mass 25 from a dropped position in which it is resting on the nut 13 into the position shown in the drawings, in which position the joggled tips 28 of the spring tongues 27, slip over and engage the collar 24. The purpose of the stop washer 23 is to limit the upward movement of the mass when being re-set, so that the tips of the tongues 27, 28 cannot foul the nut 19 and thereby disturb the calibration of the indicator. If the part to which the indicator is secured undergoes a vertical upward acceleration exceeding the magnitude for which the indicator is calibrated, the increased apparent weight of the mass 25 will be sufficient to cause the springs 27, 28 to spring over the collar 24, allowing the mass 25 to drop. After the test routine, an inspection of the indicator will show at once whether the mass 25 has dropped or not, thus giving an immediate indication of whether the assigned critical upward acceleration has been exceeded at the location of the indicator. (*Accepted June* 5, 1947.)